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INVESTIGATION OF MATERIALS PROCESSING TECHNOLOGY

D.R. BARKER, V. SEETHARAMAN
R. GOETZ

UES, INC.
MATERIALS PROCESSING AND MFG DIVISION
4401 DAYTON-XENIA ROAD
DAYTON, OHIO 45432

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WRIGHT LABORATORY
AIR FORCE MATERIEL COMMAND
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James T. Morgan

JAMES T. MORGAN
Project Engineer
Materials Behavior Branch

Allan W. Gunderson

ALLAN W. GUNDERSON, Chief
Materials Behavior Branch

Norman M. Geyer

NORMAN M. GEYER, Actg Asst Chief
Metals and Ceramics Division

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D. BARKER, V. SEETHARAMAN, R. GOETZ

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13. ABSTRACT *(Maximum 200 words)*

This report summarizes the work performed in materials processing research over the 45-month period from April 1989 through December 1992. The research work included projects on measuring the interface heat transfer coefficient in casting, predicting macro-segregation in casting, hot extrusion of TiAl alloy, canned extrusion of TiAl with core insulation, visioplasticity study of 6061 Al, cold rolling of Bi-based superconductor, and die design and process modeling of $Mg+B_4C$ alloy. The processing work in the Processing Laboratory included 2,357 extrusion, forging, rolling, vacuum arc melting, vacuum induction melting, and evacuation/outgas operations. The Processing Laboratory was also relocated as part of this program and the 700-ton Lombard extrusion press was completely rebuilt and modernized.

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FORWORD

This report was prepared by UES, Inc., Dayton, Ohio, under USAF Contract No. F33615-89-C-5600. The project was initiated under Project No. 2418 "Metallic Materials," Task No. 03 "Processing-Microstructure-Property Relationships," Wcrk Unit No. 19, Program Element 62102F. It was administered under the direction of Wright Laboratory, Wright-Patterson Air Force Base, Ohio, with Mr. J. T. Morgan as Project Engineer.

The work described in this report was accomplished between 1 April 1989 and 31 December 1992.

Full-time staff on the program included:

Douglas R. Barker, Principal Investigator
Thomas E. Jones
Travis M. Brown
Joseph O. Brown
Thomas A. Goff
J. Faye Hickman

Contributing staff included:

Venkat Seetharaman
Anil Chaudhary
Douglas Lang
Carl J. Lachey
Susan M. Wallace
Vijay Shende
Srivats Gopinath
Sudhir Machireddy
Robert Goetz

1. INTRODUCTION

The microstructure and properties of advanced high temperature, high strength materials, as well as more common structural materials, are dependent upon thermo-mechanical processing history. Increasing emphasis in both the Air Force and commercial industry on part quality, reduced cost, design optimization, reduced lead times, and conservation of energy and materials requires an improved understanding of fabrication processes.

The objectives of this program were to (1) investigate processing conditions required to obtain desired microstructures and properties, (2) implement and use analytical models for process design, and (3) validate analytical models by physical modeling.

During the course of this program, UES was also given the task of relocating and modernizing the Experimental Materials Processing Laboratory. Approximately 50% of the program effort was directed to this task.

2. RESEARCH ON ANALYTICAL AND PHYSICAL MODELING

2.1 Determination of Interface Heat Transfer Coefficient in Al Casting

2.1.1 Task Summary

Experimental and analytical techniques were developed to determine the interface heat transfer coefficient at the metal-mold interface in casting. The Vacuum Induction Melter (VIM) in the Processing Lab was instrumented and a specialized data acquisition system was developed to measure cooling curves in experimental castings. Experiments on aluminum, In-718 and 17-4 stainless steel were performed in the Processing Lab and in the Howmet research foundry. An inverse Finite Element Code was used to back calculate the interface heat transfer coefficient using the experimental data as an input. This task was a cooperative project with UES, General Electric and Howmet.

2.1.2 Task Background

Numerical simulation of the metal casting process has, in recent years, reached the stage where it can now be applied to complex commercial castings. The use of simulations in designing castings can both increase product quality and reduce cost. To fully realize such benefits, process simulations must be both accurate and cost effective. One of the hurdles that must be overcome is the development of a database of materials properties and boundary conditions. One of the important data required for modeling of solidification is the mold-metal interface heat transfer coefficient, since the heat extraction from metal through mold is dependent on this coefficient value. Moreover, the interface heat transfer coefficient depends on many different factors, including:

- temperature of solidifying material
- expansion/contraction characteristics of casting and mold material
- formation of air gap between casting and mold
- application of pressure over metal during solidification
- shape and size of casting
- interface mold coat

- chemistry of casting and mold material
- casting environment (under vacuum, inert gas or atmosphere)

Out of these, the temperature of solidifying material and the air gap formation between casting and mold have the greatest influence over the heat transfer coefficient. In this task, the interface heat transfer coefficient is determined as a function of solidifying material temperature.

2.1.3 Objective

To design and develop an experimental setup and analysis technique to determine mold-metal interface heat transfer coefficient as a function of temperature for different casting and mold materials.

2.1.4 Approach

The following approach was used for the determination of interface heat transfer coefficient.

1. A cylindrical casting and mold shape were selected to promote essentially unidirectional heat transfer. The selected cylindrical casting will be height-to-diameter ratio of approximately 2:1.
2. Four or more thermocouple locations were used in each casting to establish the temperature gradients on either side of the interface. As a safety precaution to thermocouple failure, thermocouple positions were duplicated at the diametrically opposite side.
3. The temperature-time data from the thermocouples was collected using a computer based data acquisition system, so that the data could be readily smoothed, averaged and formatted for analysis as required.
4. The finite element code IHEAT was used to back calculate the Interface Heat Transfer Coefficient (IHTC).

2.1.5 Experimental Techniques

Data Acquisition System: A computer aided data acquisition system was designed and assembled based upon a Compaq 286 microcomputer with Data Translations signal conditioner,

cold junction and analog I/O boards. The computer software handles the recording of up to 16 thermocouple inputs. The software was designed specifically for use in casting experiments and has several special features such as triggering of data recording when any thermocouple hits a selected threshold temperature and a real time display to help evaluate when the test can be ended during metal cooling. For the experiments at the Howmet foundry, a second data acquisition system was assembled based on a portable Epson laptop computer.

Vacuum Induction Melter (VIM) Modifications: The VIM was upgraded and modified in order to perform the required experiments. Thermocouples, extension cables, terminal jacks and vacuum feedthroughs were installed for powering the mold preheat furnace and for thermocouples.

Molds: Both copper and ceramic molds were used in these experiments. The copper mold was fabricated in-house. This mold has an insulated bottom to reduce the amount of vertical chill that otherwise occurs in a metal mold. Platinum thermocouples were positioned in the mold wall and in the mold cavity.

Pouring Conditions: The ceramic molds were heated to 1800°F in a clamshell resistance furnace placed inside the VIM. All of the castings were conducted in vacuum or argon atmosphere.

2.1.6 Castings

Pure Aluminum Castings: An instrumented pouring of pure aluminum into the copper mold was successfully performed (casting no. 199). Data were collected from four thermocouples. Thermocouple locations and cooling curves are shown in Figure 1. The casting was split, polished and etched to confirm that the thermocouples were in an area of directional heat flow perpendicular to the wall. The microstructure was columnar perpendicular to the wall, implying radial heat flow, as desired.

A357 Aluminum Castings: An instrumented pouring of A357 aluminum alloy was made into the copper mold (casting no. 203). Data was collected from 16 thermocouples. The thermocouple locations are shown in Figures 2 and 3. The cooling curves are shown in Figures 4 through 6. The critical thermocouples were all duplicated on opposite sides of the casting in order to eliminate any nonsymmetric effects created during pouring. Two thermocouples (#0

and #1) were also inserted vertically, from the bottom of the casting, in order to determine if radially inserted thermocouples give different results from vertical thermocouples along isotherms. There was not any significant difference. A thermocouple (#14) was also placed at a different height in the casting, directly below another thermocouple (#10) in order to directly measure the validity of the radial heat flow assumption. It was found that a height difference of 0.5" had no effect on temperature readings, so we conclude that the heat is exclusively radial in the vicinity of the thermocouples.

IN-718 and 17-4 Castings: At Howmet Corporation, nine instrumented castings were made of IN-718 and 17-4. Melting was performed in the upper furnace chamber in a vacuum. Immediately after pouring into the hot ceramic mold, the mold ram was lowered into the bottom chamber. Once in the bottom chamber, the casting was allowed to cool under the specified atmosphere: vacuum, argon or air.

Each mold was fitted with four thermocouples. Cooling curves for one of the 17-4 stainless steel castings are shown in Figure 7. Cooling curves for one of the IN-718 castings are shown in Figure 8.

2.1.7 Data Analysis

A Finite Element Code, IHEAT, was developed that back calculates the heat transfer coefficient as a function of the cast metal temperature. The inputs to this program are the geometry, thermocouple locations, properties of the metal and mold, and the thermocouple readings from the experimental casting.

A data smoothing program, SMOOTHER, was written to reduce and smooth the experimental data from HOTSHOT.

For each casting condition the best data were selected and run through the IHEAT code. The output are the Temperature Profile plots, that show the radial temperature distribution, and the Interface Heat Transfer Coefficient (IHTC) as a function of metal temperature. These plots are shown for the A357, 17-4 and IN-718 in Figures 9 through 14.

2.1.8 Discussion

A successful experimental and analysis procedure has been developed and demonstrated

for obtaining the Interface Heat Transfer Coefficient. The versatility and robustness of the technique were certainly demonstrated by the successful transportation of the entire system to a commercial foundry.

The temperature profile plots generated by IHEAT behaved as expected. The IHTC plots shown here are of a reasonable order of magnitude, with some oscillations that appear to be numerical effects.

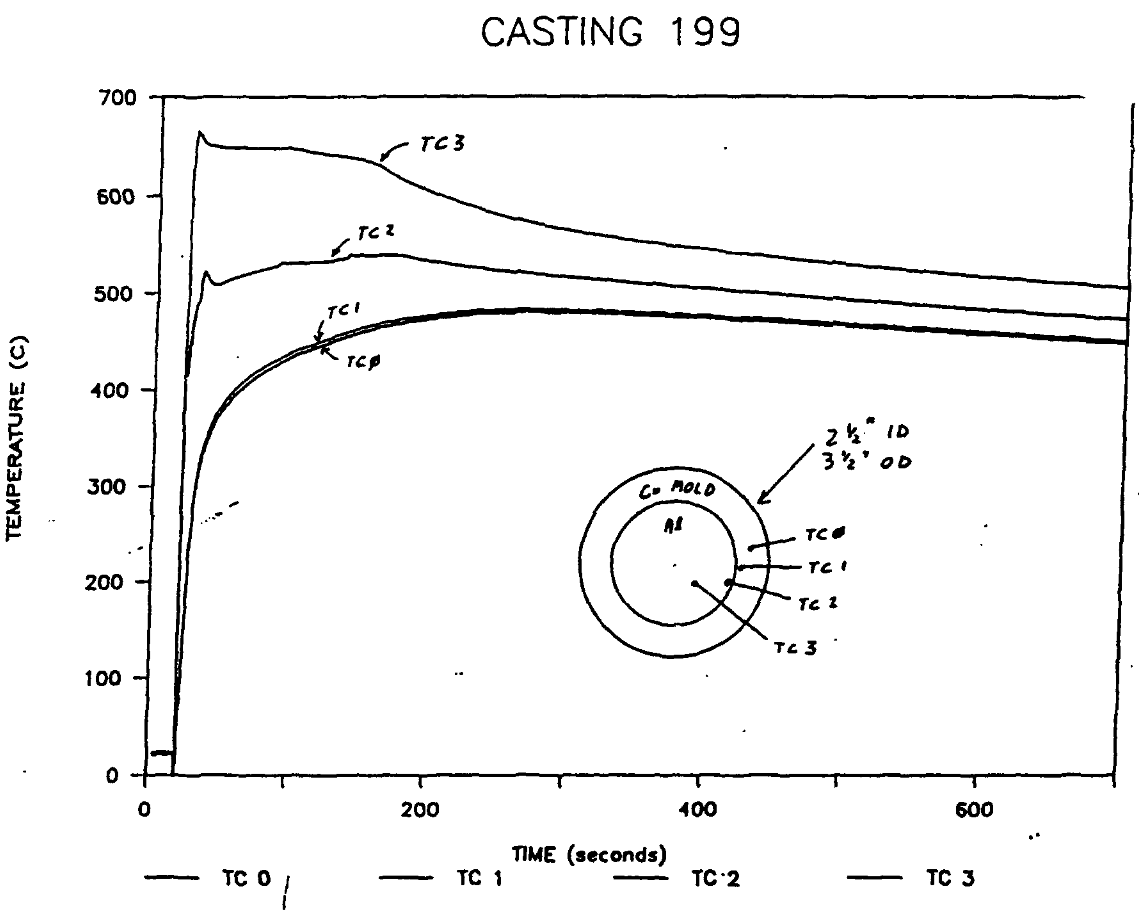

Figure 1: Cooling curves for Al casting in Cu mold

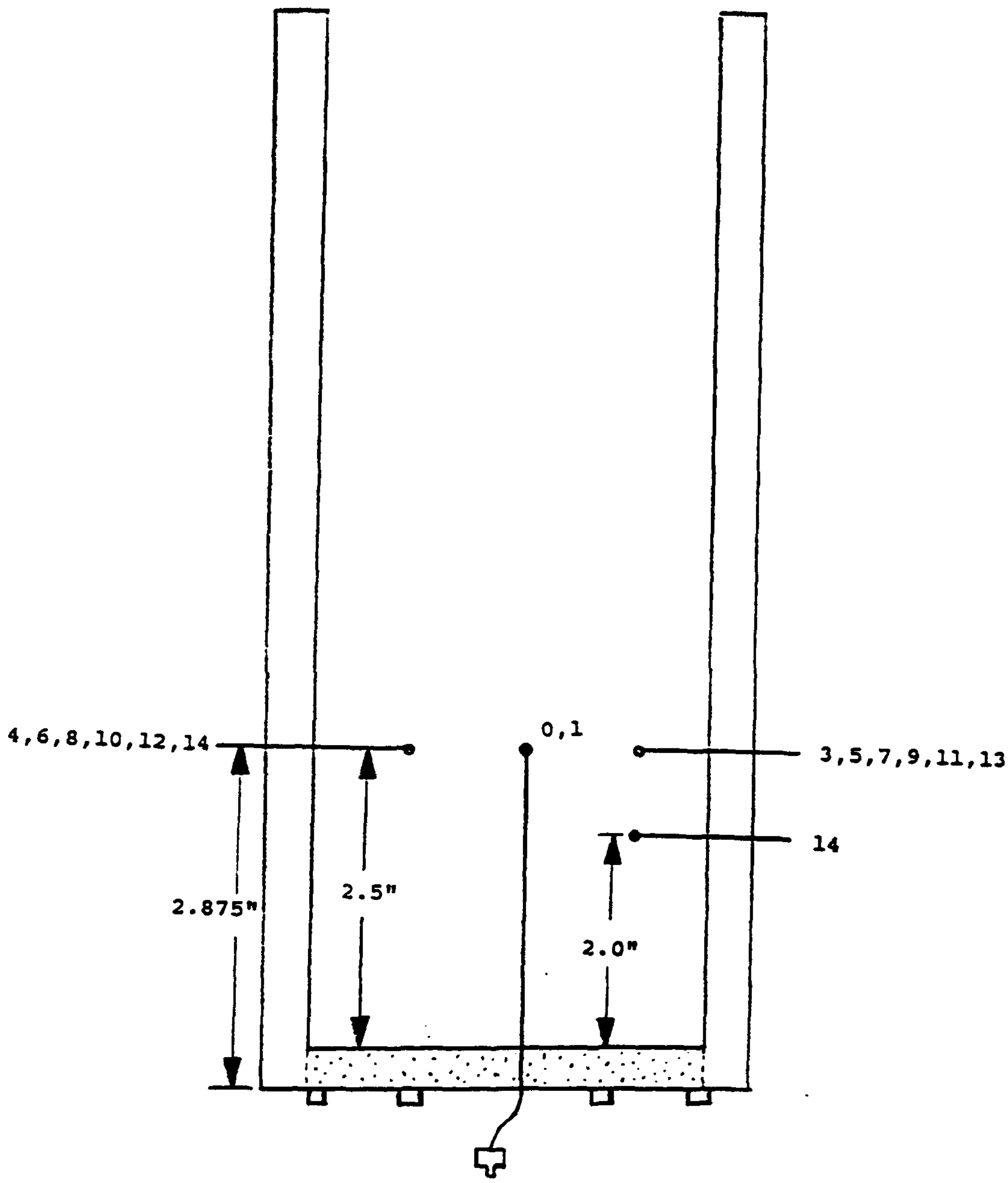

Figure 2: Thermocouple locations in A357 casting

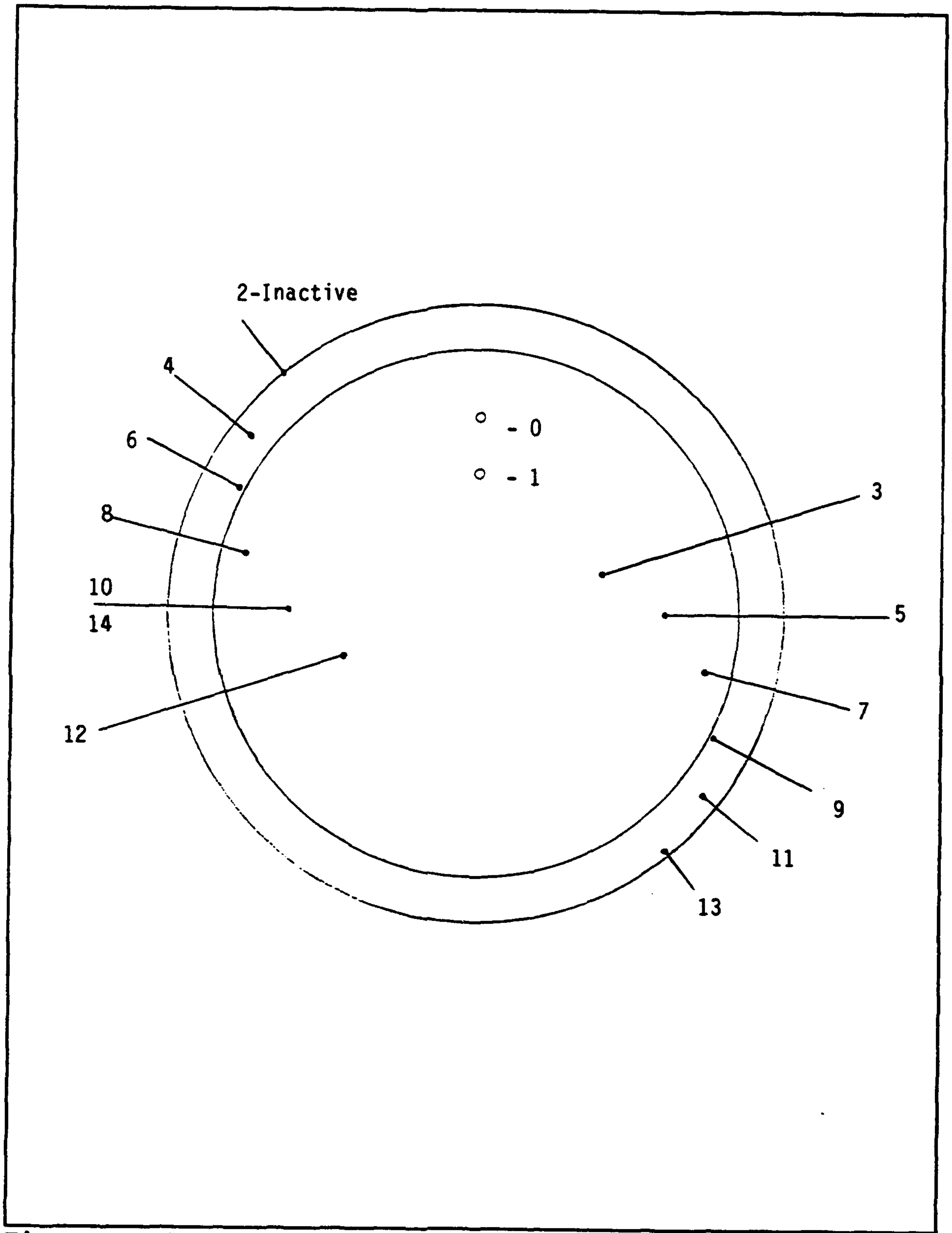

Figure 3: Thermocouple locations in A357 casting

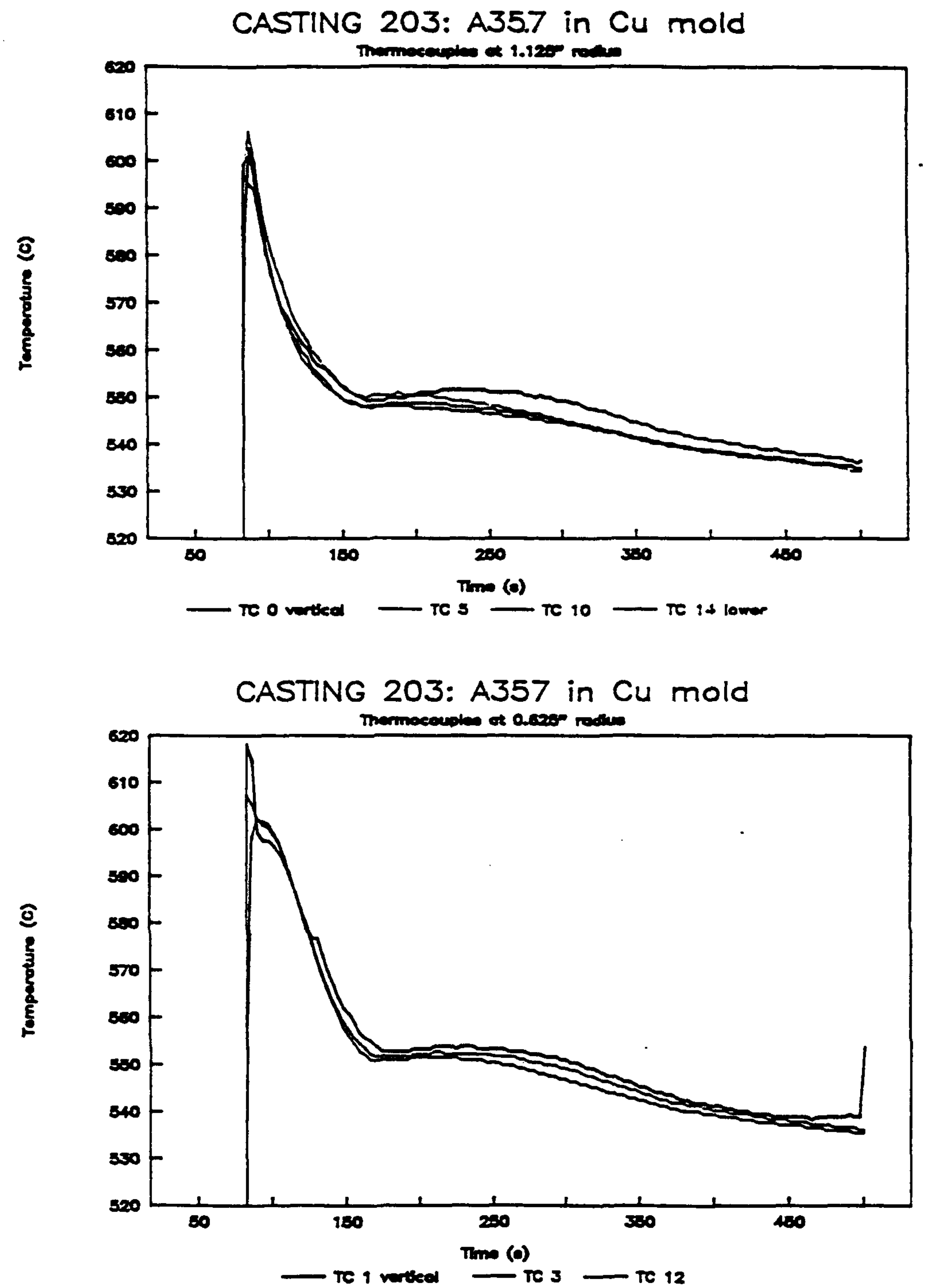

Figure 4: Time-temperature curves of A357 casting in Cu mold

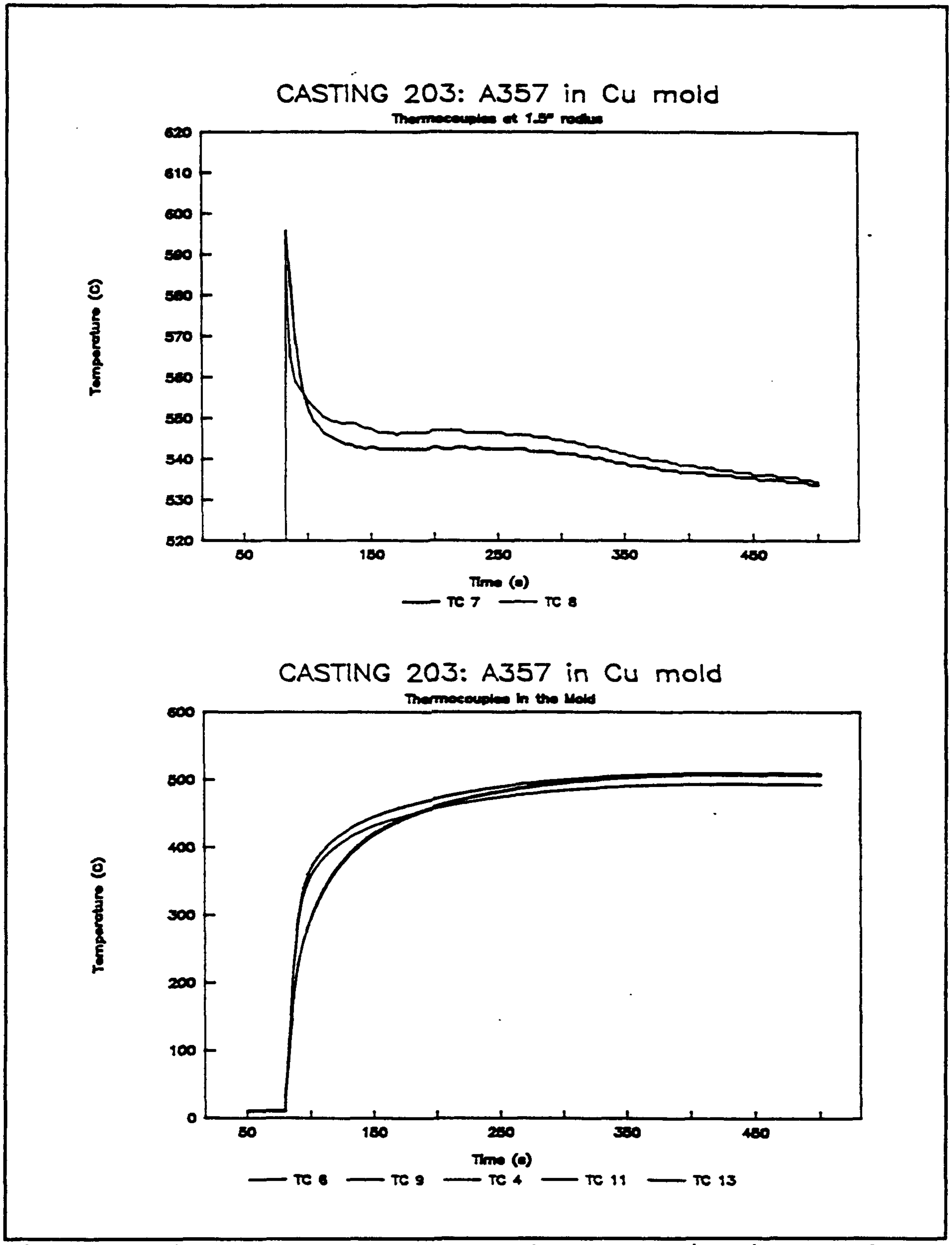

Figure 5: Time-temperature curves of A357 casting in Cu mold

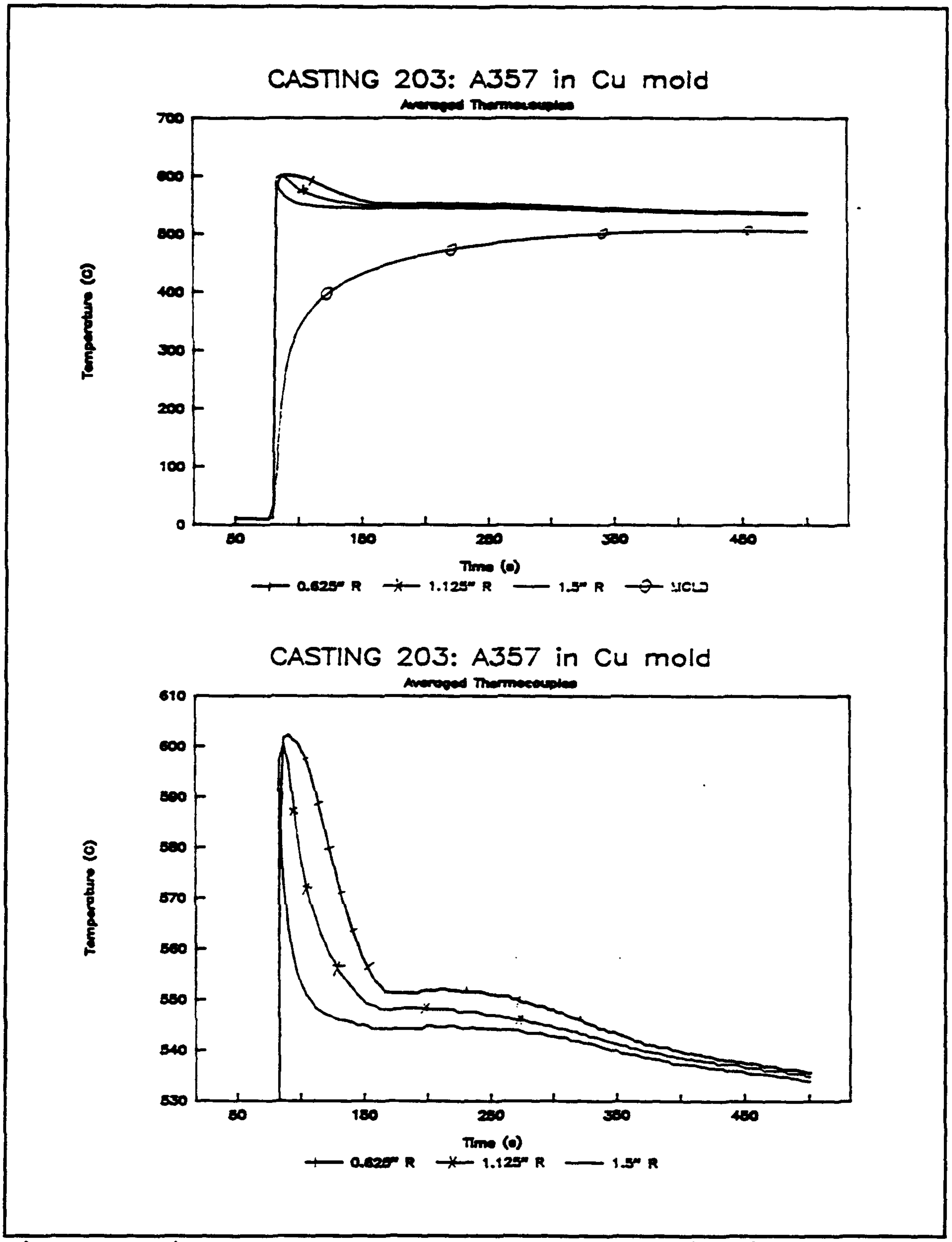

Figure 6: Time-temperature curves of A357 casting in Cu mold

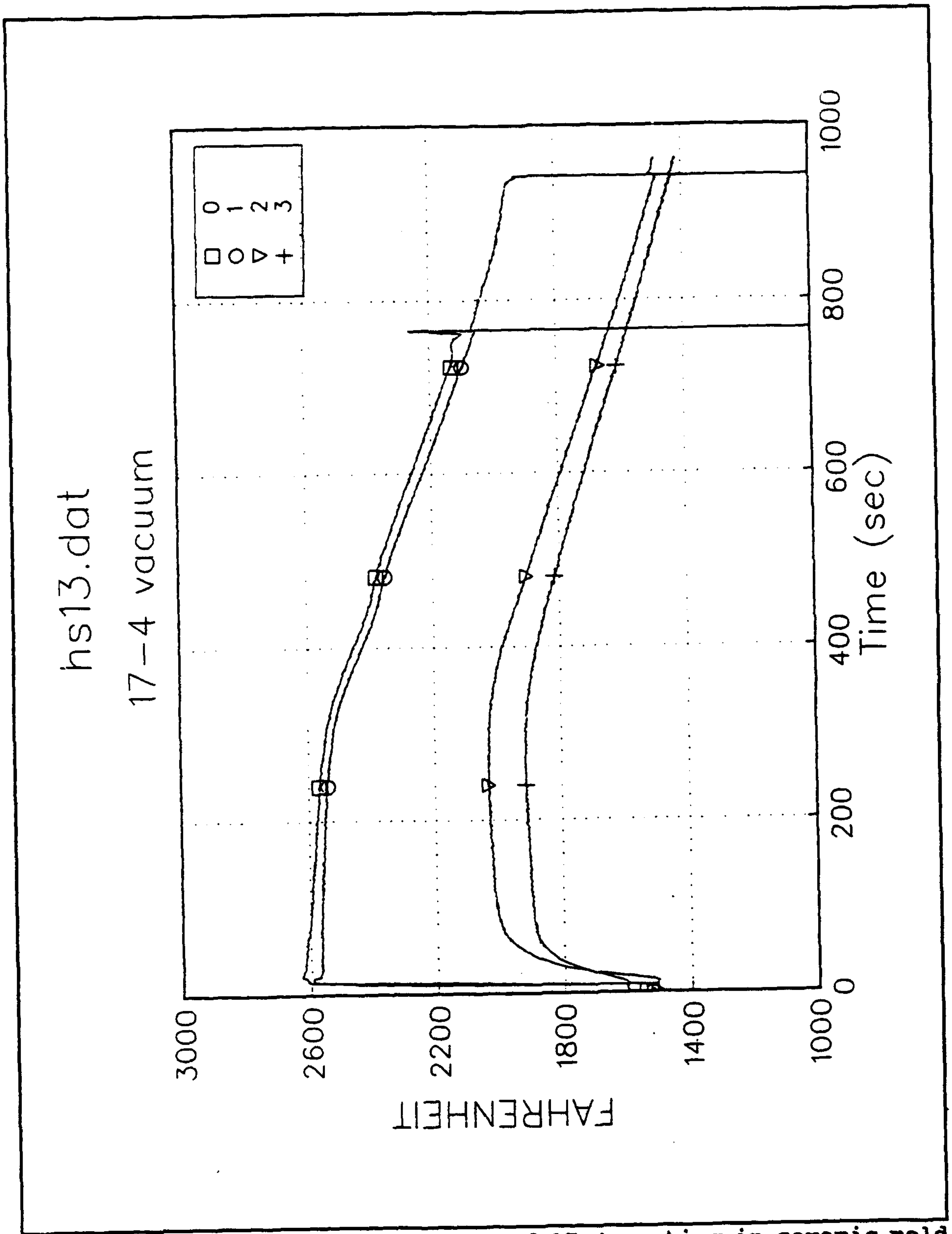

Figure 7: Time-temperature curves of 17-4 casting in ceramic mold

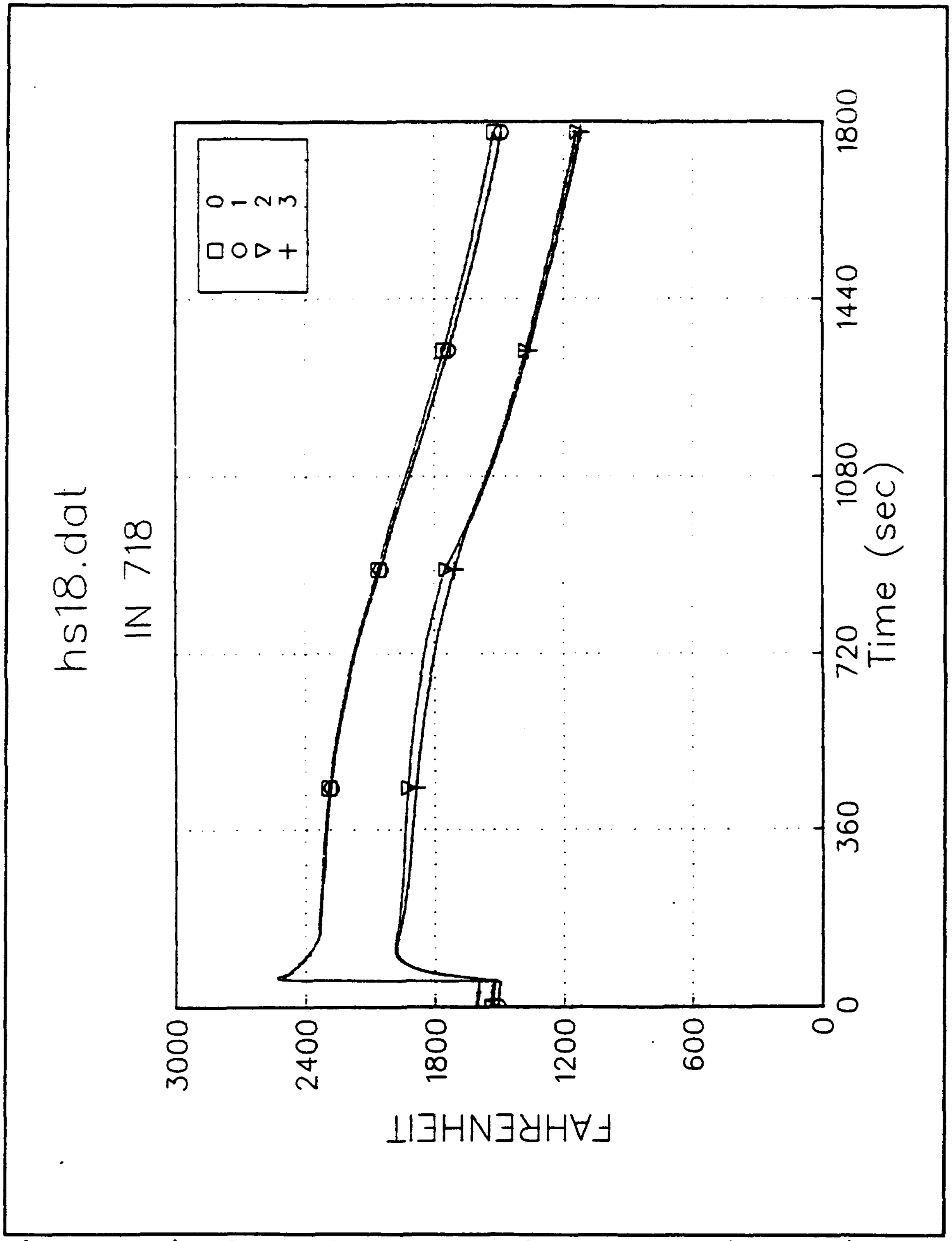

Figure 8: Time-temperature curves of IN-718 cast in ceramic mold

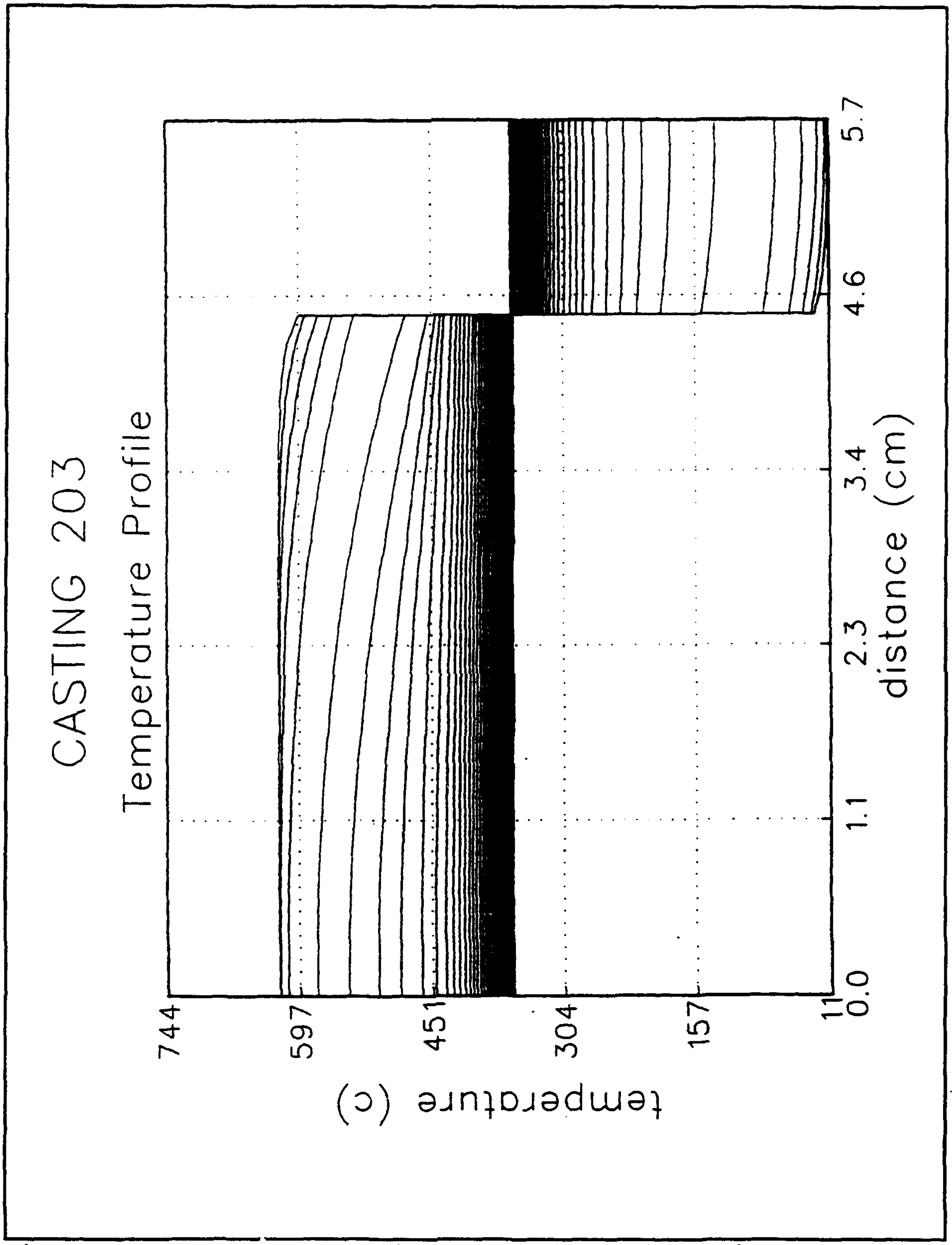

Figure 9: Temperature profiles from IHEAT simulation of A357

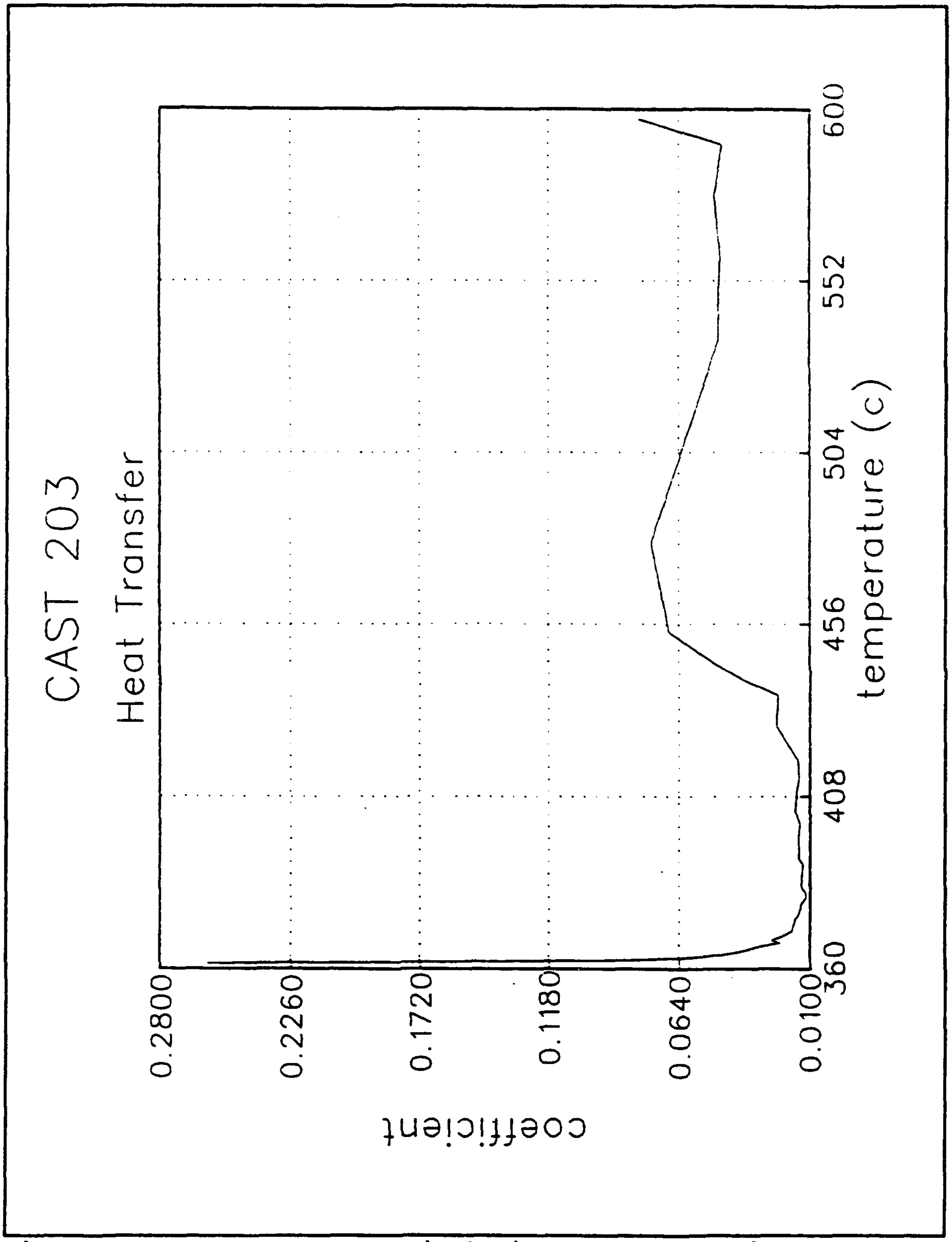

Figure 10: IHTC from IHEAT simulation of A357 casting

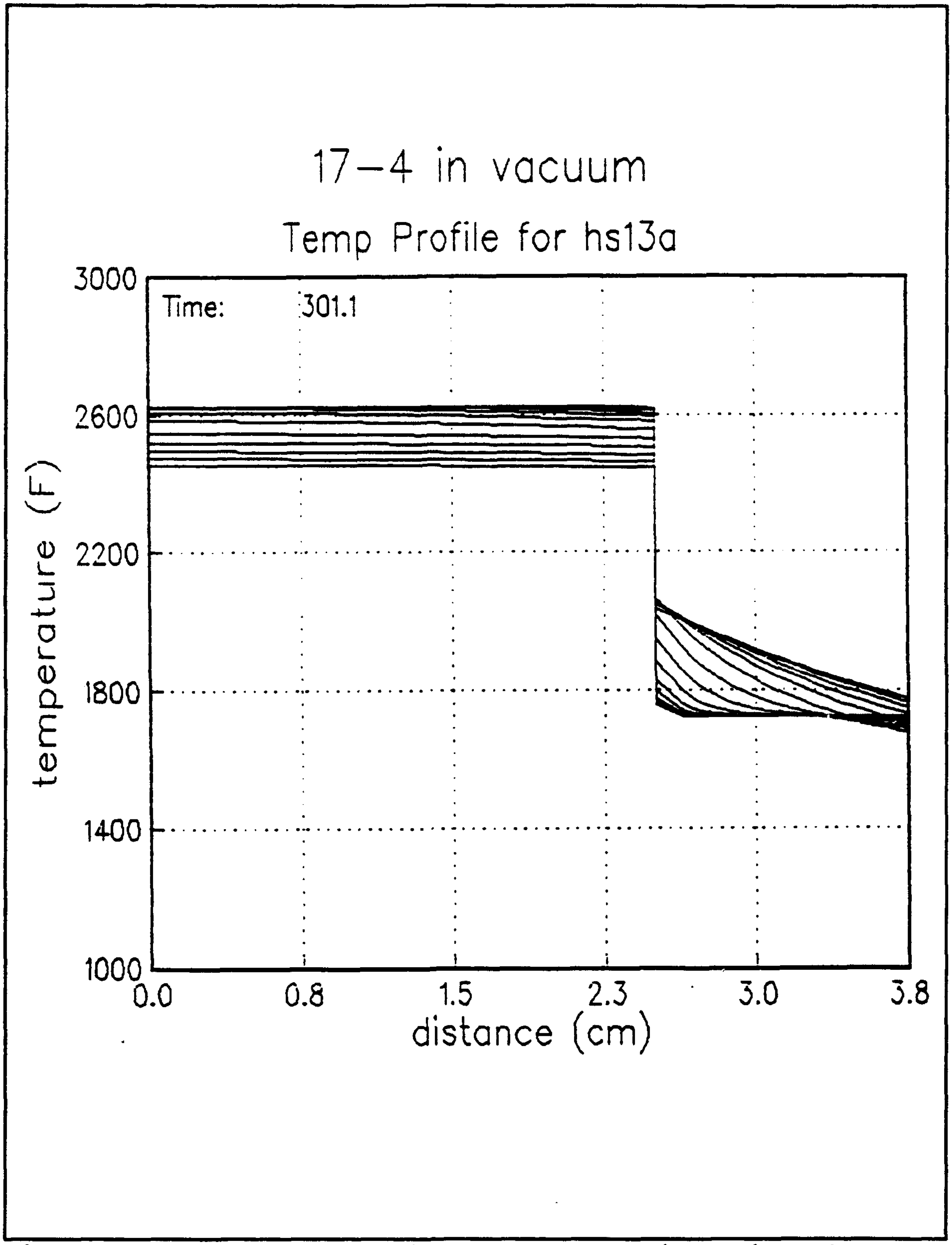

Figure 11: Temperature profiles from IHEAT simulation of 17-4

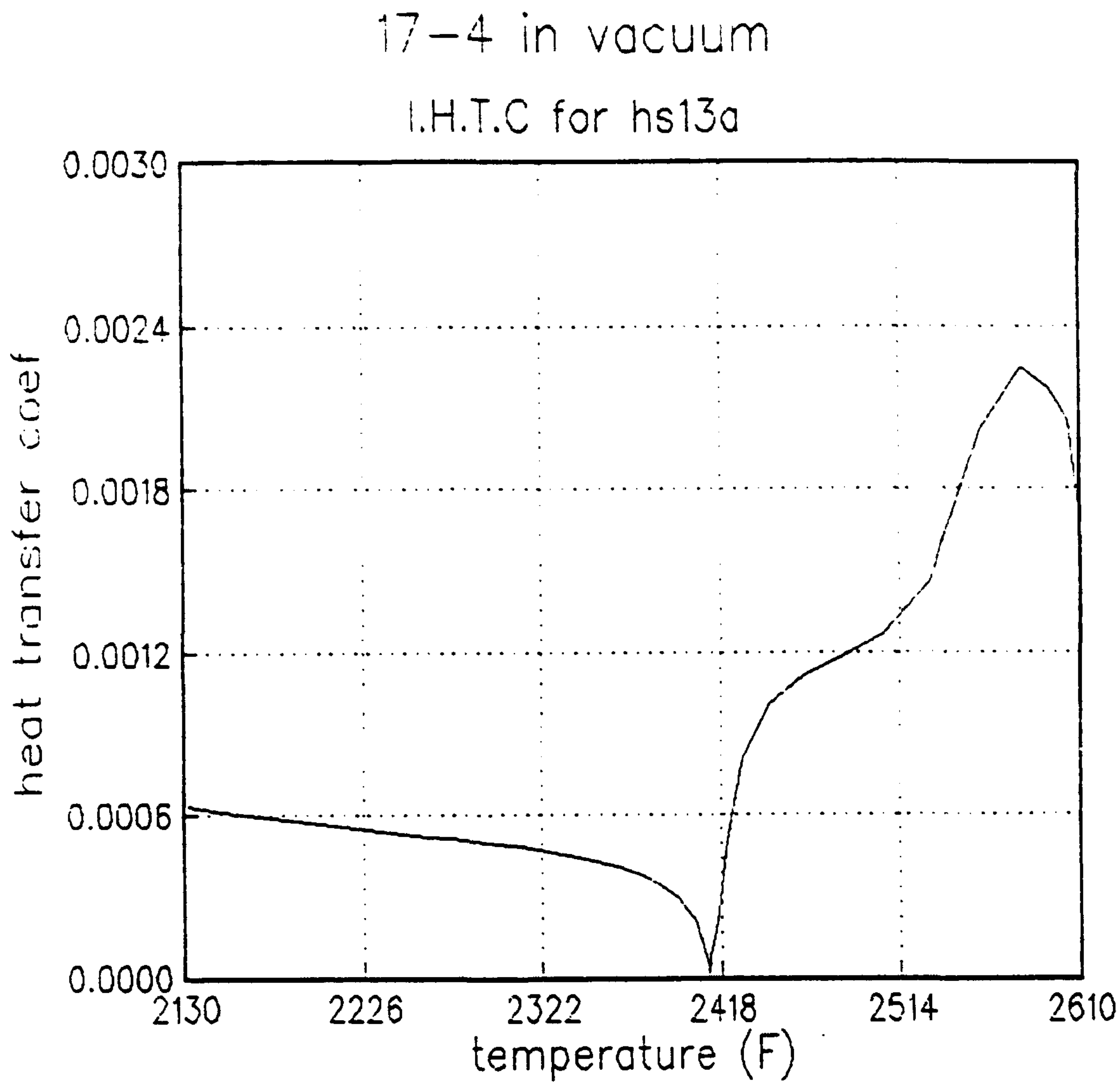

Figure 12: IHTC from IHEAT simulation of 17-4 casting

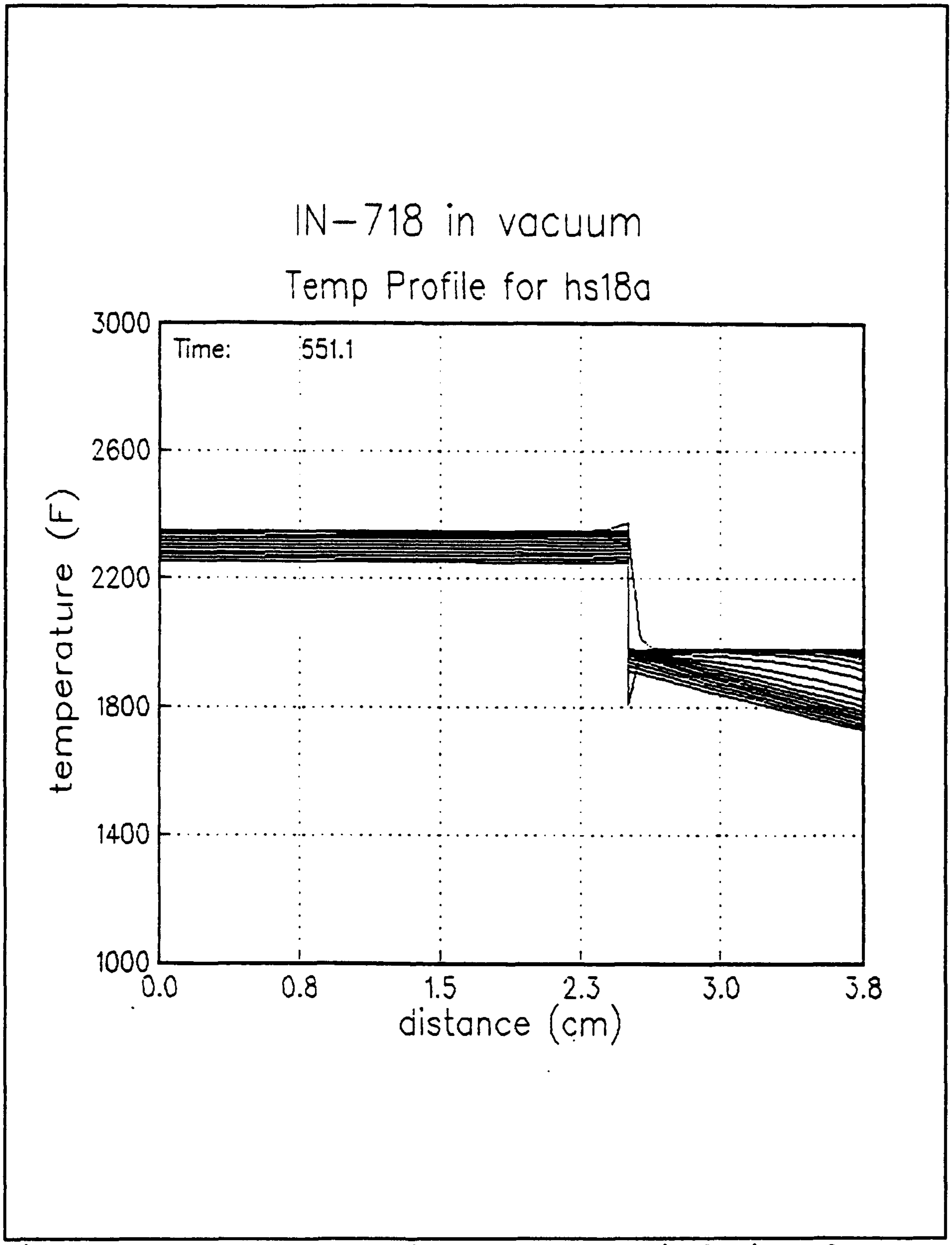

Figure 13: Temperature profiles from IHEAT simulation of IN-718

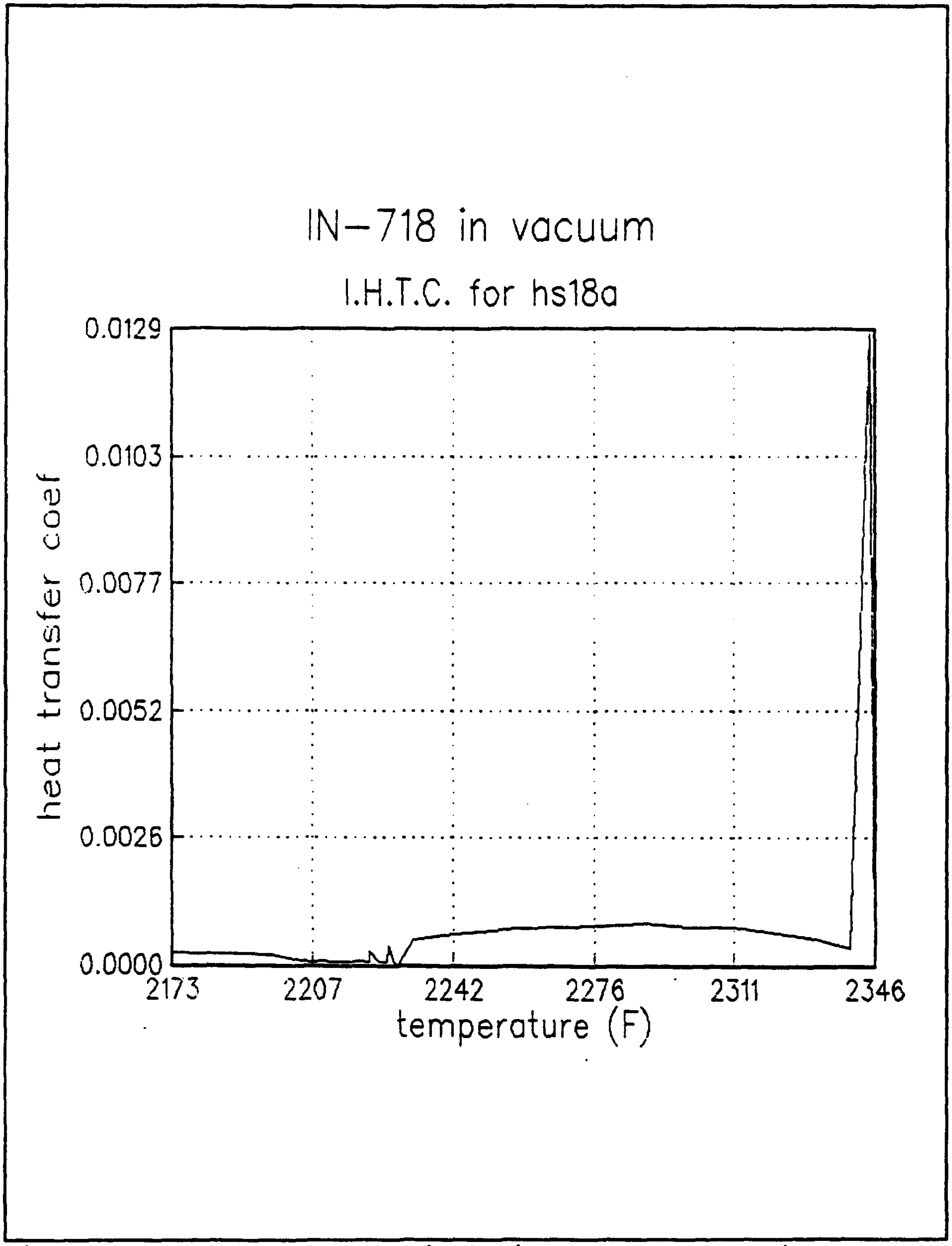

Figure 14: IHTC from IHEAT simulation of IN-718 casting

2.2 Determination of Interface Heat Transfer Coefficient in Ti Castings

In this task, the Interface Heat Transfer Coefficient (IHTC) between the metal and the mold was determined for the casting of Ti-6Al-4V into a ceramic investment shell. This work was done as a cooperative research task between TiLine, General Electric, UES and the KIDS Program (AF contract F33615-89-C-5619).

The IHTC has an exceptionally strong influence on the solidification behavior of titanium castings. Titanium must be poured into its mold at a temperature only slightly above its melting point, so heat transfer has a big impact on mold filling and on the depth of the formation of alpha case.

There are, at present, no methods for predicting the IHTC from either first principles or from simulations based upon fundamental properties of the metal and the mold. In fact, the value of the IHTC is highly dependent upon a number of factors that are unique to specific foundry mold and melt practices, as well as mold geometry. Thus, the best way to characterize the IHTC is to conduct experiments in the same foundry where the production parts will be made. This is especially true for castings that are highly sensitive to the values of the IHTC, such as titanium castings.

A methodology for determining the IHTC of castings had already been developed and proved in the Processing Lab (see Section 2.1). However, the Processing Lab is not equipped for titanium castings for two reasons: (1) the melting of titanium is extremely dangerous and requires specialized equipment; and (2) results of IHTC determination for titanium casting will be highly dependent on specific foundry practice. Rather than spending a great deal of time and money trying to duplicate casting conditions at TiLine, it was decided to conduct experiments in TiLine's foundry.

TiLine prepared six ceramic molds, equipped with thermocouples, as shown in Figure 15. Each mold contained three thermocouples in the shell wall and three thermocouples within the mold cavity. The thermocouples were calibrated type "C" probes (i.e., Tungsten-5%Rhenium / Tungsten-26%Rhenium) custom made by Omega to part number XMO-W5R26-U-062-40-A-TJ-3-IB. Pourings were all made in vacuum. In some cases the chamber was backfilled with an inert gas immediately after pouring was complete. This inert gas helps cool the mold and speed solidification. Variables in the tests were the ceramic mold preheat

temperature and the cooling media used during solidification. The test conditions are detailed in Table 1.

UES personnel traveled to the TiLine foundry in Albany, Oregon, with a portable data acquisition system. The six experiments were all successful. A typical set of cooling curves is shown in Figure 16. The IHTC was determined from each of the castings. A typical IHTC curve is shown in Figure 17, where it is plotted as a function of the temperature of the titanium.

Table 1: Test conditions for Ti-64 castings

	Fired Shell*	As-Cast**					
	Shell	Cooling	DIA. (IN)		DIA. (IN)		α-CASE***
Mold #	Preheat	Media	Low	High	Low	High	Thickness
1	RT	IG	2.027	2.032	1.969	2.005	.031
2	1200°F	IG	2.023	2.029	1.966	2.018	.032
3	RT	IG	2.025	2.042	1.981	2.015	.032
4	RT	Vacuum	2.024	2.033	1.982	2.019	.052
5	1200°F	IG	2.024	2.033	1.977	2.004	.035
6	1200°F	Vacuum	2.020	2.028	1.968	2.013	.031

* Checked by Telescoping Gauge and Dial Calipers

** Checked by Dial Calipers

*** Certified α-Case Analysis and Micrographs available on request.

RT = Room Temperature

IG = Inert Gas

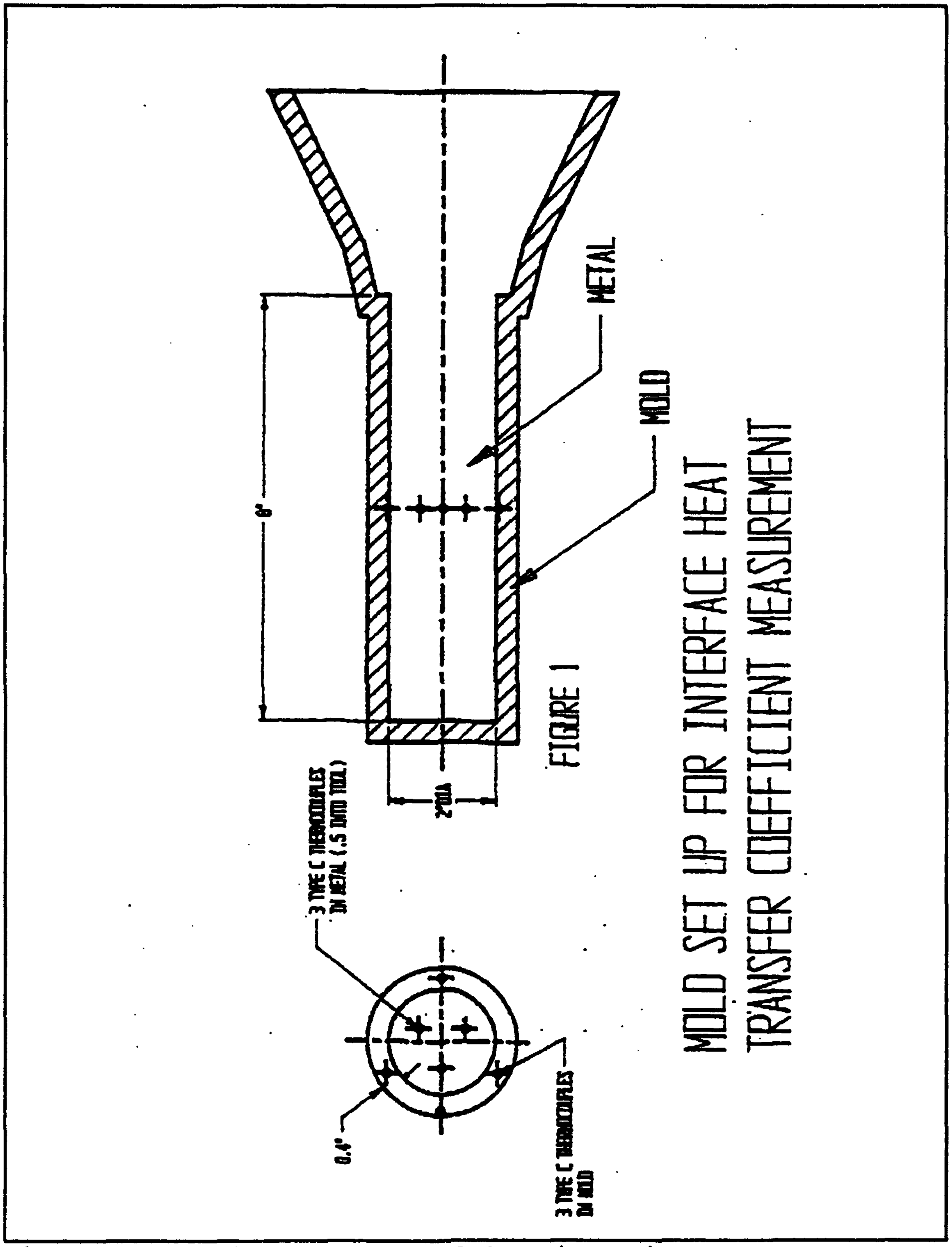

Figure 15: Drawing of mold used for Ti castings

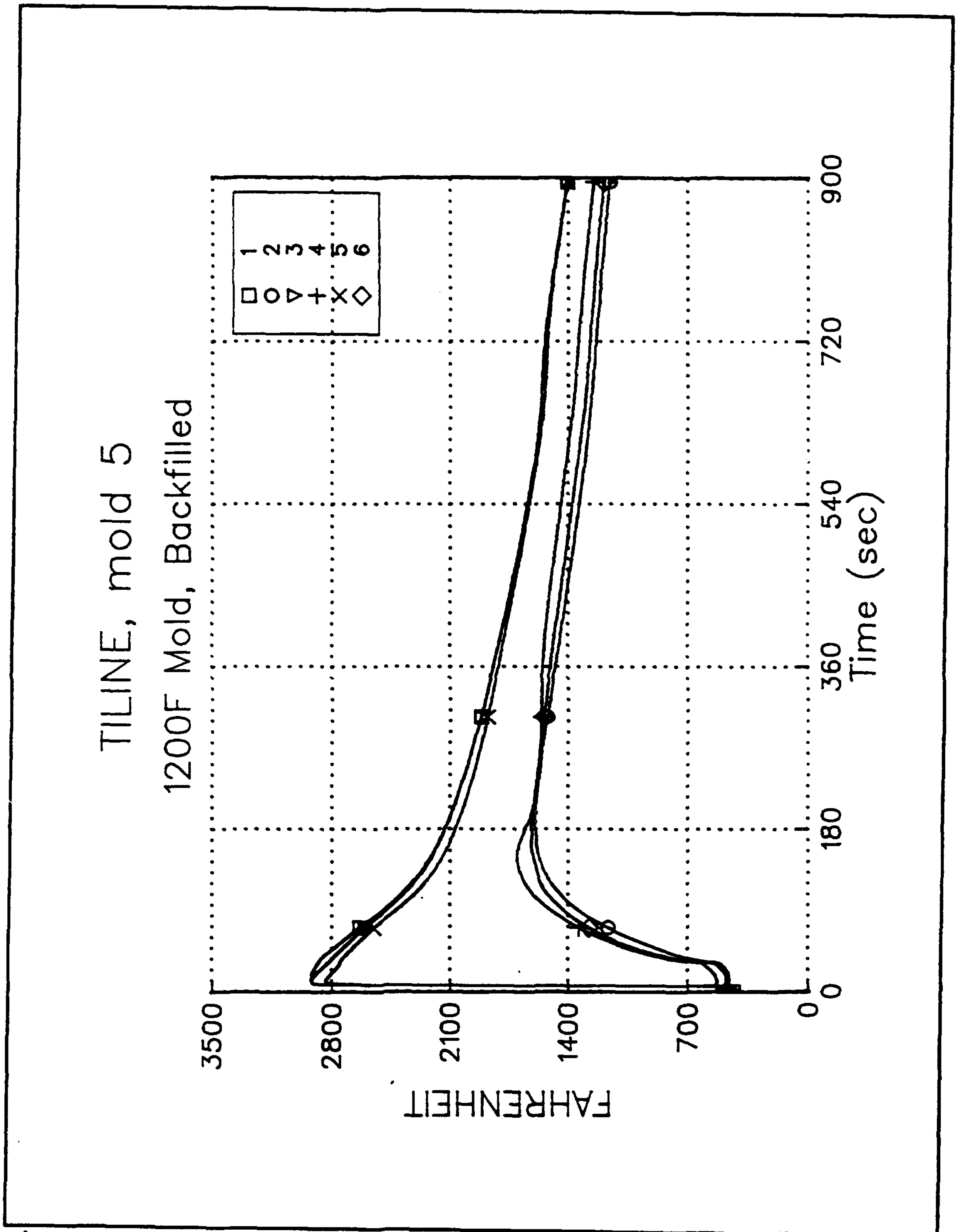

Figure 16: Cooling curves for a Ti casting in ceramic mold

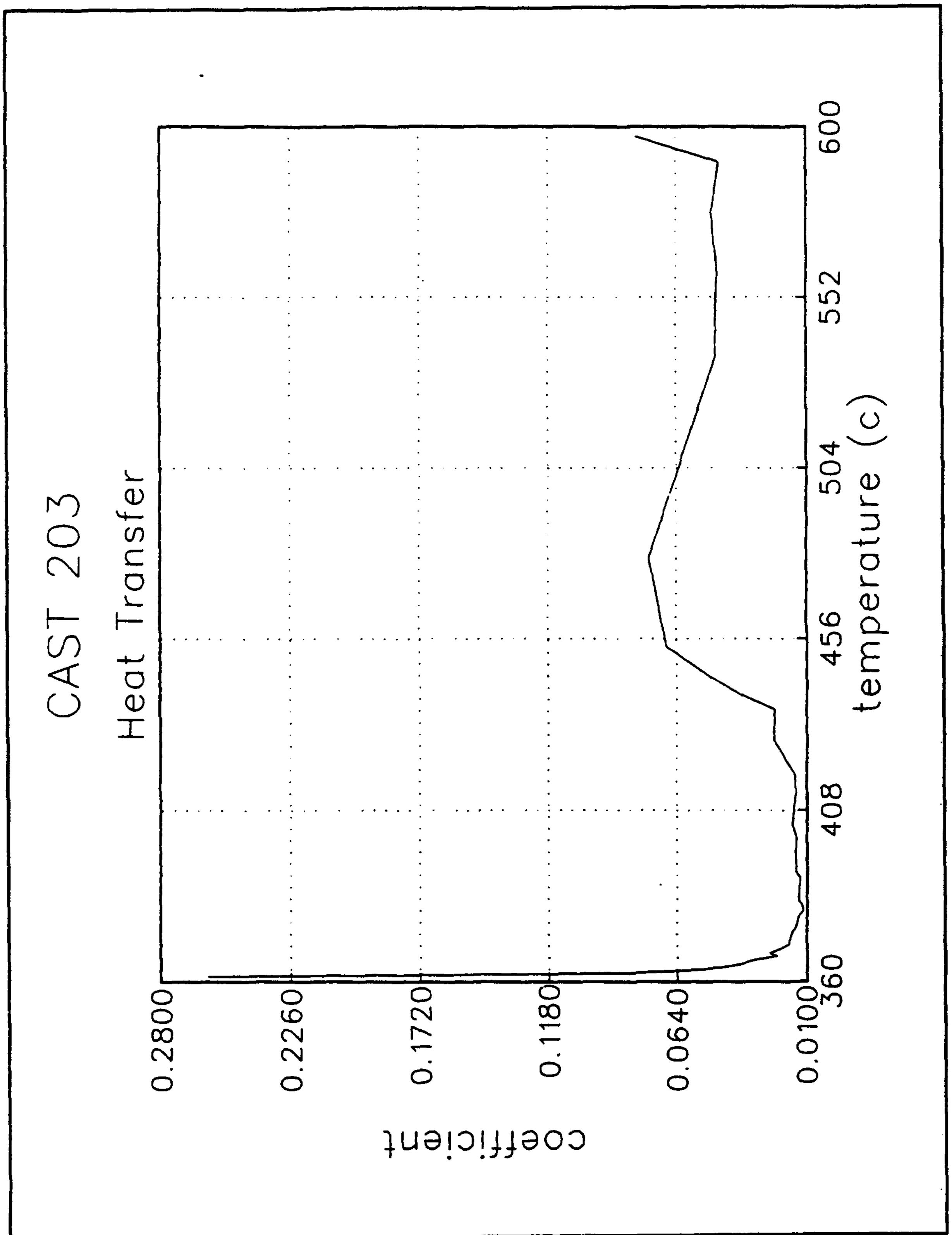

Figure 17: Interface Heat Transfer Coefficient for Ti casting

2.3 Prediction of Macrosegregation in Metal Casting

2.3.1 Task Summary

Macrosegregation is a common phenomenon during solidification of large ingots or castings and manifests itself in different forms: centerline segregation, banding, channel segregation (type A or V) in large steel castings or freckles in directionally solidified superalloy castings. While most forms of macrosegregation are undesirable, one form associated with plane front solidification is very beneficial and is exploited as the zone refining technique for obtaining high purity materials. Seminal work carried out by Flemings and his coworkers established that a single mechanism involving the flow of solute rich interdendritic liquid in the mushy zone during solidification is responsible for most types of macrosegregation. Interdendritic fluid flow occurs as a result of solidification shrinkage and the force of gravity acting on a liquid of variable density.

The most important factors influencing macrosegregation are (a) the ratio (V_n/U) of interdendritic fluid velocity Vn to the velocity of the isotherms, U and (b) the solidification shrinkage parameter β defined as $\beta = (\rho_s - \rho_L)/\rho_s$ where ρ_s and ρ_L are the densities of the solid and liquid phases, respectively. Negative segregation (or flow of interdendritic liquid from hotter to cooler regions) has been shown to occur whenever large changes in the section size occur in the path of solidification. In contrast, positive segregation usually occurs at the mold wall or chill surface. Experiments performed on horizontally solidifying systems have shown the importance of thermo-solutal convection and its effect on the interdendritic fluid flow.

Recent studies on multidirectional solidification by Ridder, et al. and Bennon and Incropera have addressed the important problem of the combined fluid and heat flow in both the mushy zone and the bulk liquid and its effect on the macrosegregation profiles. The results reported by Ridder, et al. revealed that convection in the bulk liquid is only weakly coupled to the interdendritic flow. Furthermore, it has been demonstrated that while the convection in the bulk liquid exerts a marked influence on the thermal field, the heat transfer in the mushy zone is relatively unaffected.

The present study represents an extension of the scope of the CAST-3 finite element code to model the interdendritic fluid flow and predict the thermal behavior as well as the

macrosegregation profiles in arbitrary three-dimensional castings. In order to validate the revised CAST-3 code, unidirectional casting experiments were performed using dilute Al-Cu alloys. The experimental data on macrosegregation profiles and the thermal analysis are compared with the numerical simulations performed using CAST-3.

This task was performed as a collaborative research effort with the Processing Science Program (Contract No. F33615-86-C-5067).

2.3.2 Experimental Procedure

A simple unidirectional solidification apparatus, as shown schematically in Figure 18 was constructed. It consisted of a water-cooled copper chill plate attached to a cylindrical insulating mold made of a riser tube suitable for aluminum alloys. The mold was equipped with fast response, insulated chromel-alumel thermocouples located at different distances away from the chill. The majority of the thermocouples were located at the centerline of the mold. However, a few were located at different radial locations, including the mold wall. All the thermocouples were monitored simultaneously using a specially designed and built data acquisition system.

High purity aluminum (>99.99%) and copper (>99.99%) were used to prepare dilute, binary alloys containing 4.5 wt% copper. Melting and casting of this alloy into the unidirectional solidification apparatus were carried out in a vacuum induction furnace, back-filled with argon at 0.5 atmosphere. In the initial experiments, elemental aluminum and copper were charged directly into the alumina crucible, slowly heated up to 700°C, held for about 5 minutes and the liquid alloy was quickly poured into the mold. However, in the subsequent experiments, copper was separately premelted with known amount of aluminum in an arc furnace and then melted along with the remaining charge of aluminum in the induction crucible. This additional step was useful in avoiding the incomplete melting of the copper pellets in the crucible.

The mold was water cooled well before the alloy was cast into it and the water cooling was continued for at least 30 minutes after pouring. The output of all the thermocouples were recorded for 30 minutes. In order to avoid any lag in the initial temperature measurement, the recording was begun a few minutes before the casting. The casting was allowed to cool for at least 2 hours before it was removed from the mold.

The castings were sectioned longitudinally through the centerline, ground, polished and

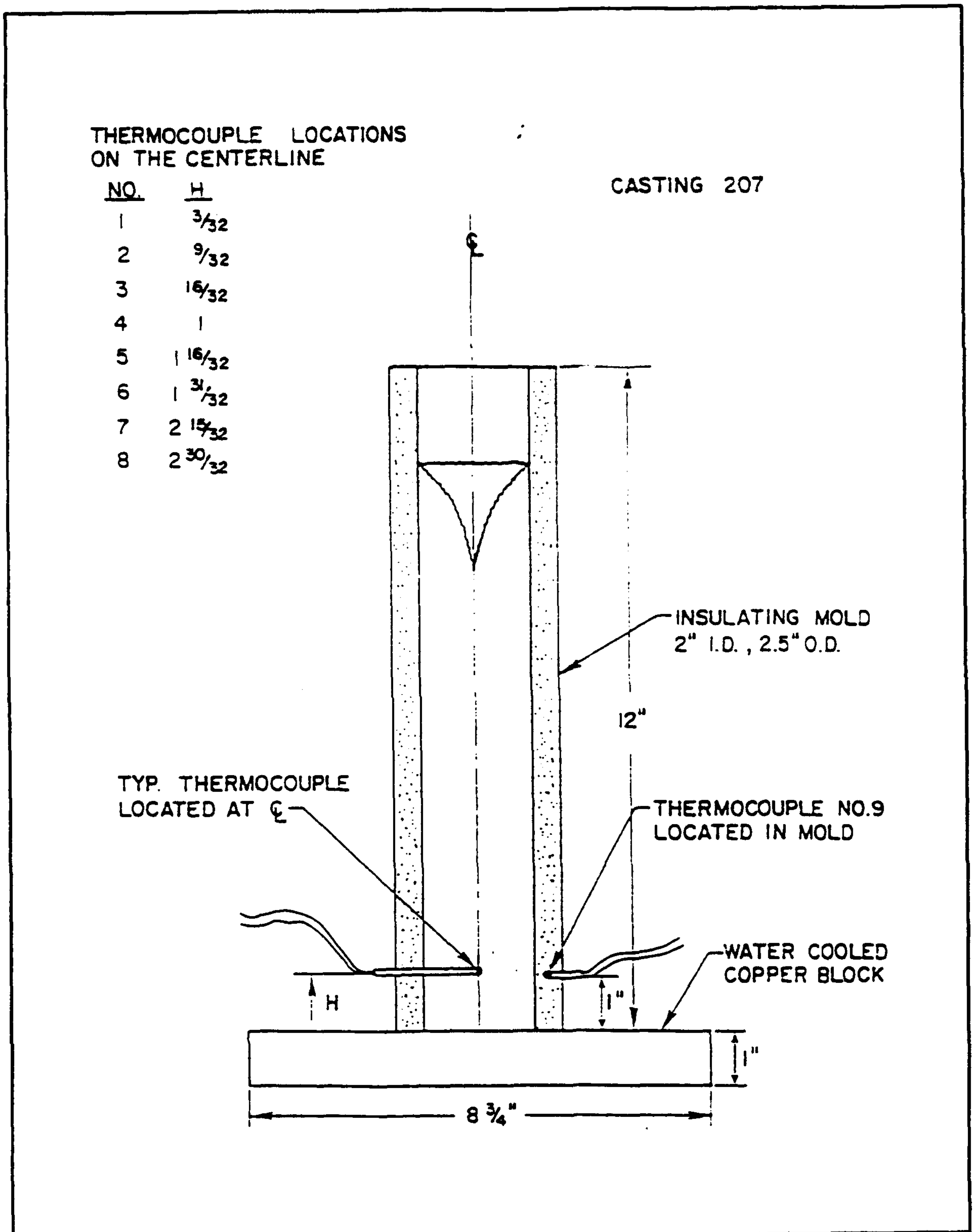

Figure 18: Schematic view of unidirectional solidification apparatus

etched to reveal their macrostructures. Specimens for wet chemical analysis were electro-discharge machined in the form of 0.2 x 0.1 x 1 inch bars, so that chemical analysis could be performed at nominal intervals of 0.2 inch along the length of the casting. Care was taken to avoid the inclusion of embedded thermocouple segments in the samples for chemical analysis.

2.3.3 Results and Discussion

The macrostructure of the unidirectionally cast ingot Al-4.5%Cu alloy revealed columnar grains parallel to the cylindrical axis near the bottom of the casting and equiaxed grains at all other locations. The height of the columnar zone is approximately 70 mm (2.8 inches). Very fine equiaxed grains form above this height and the grain size of the equiaxed grains increases gradually from about 1 mm to 10 mm near the top of the casting. It should be pointed out that no grain refining additives such as TiB_2 or TiAl were added to the melt. Moreover, since the alloy was melted and solidified in high purity inert gas atmosphere, the inclusion content was quite low. If some oxide or silicate inclusions were present, these would have resulted in grain refining, although TiB_2 additions would be certainly very effective. In view of the above reasons, it is not surprising that the grain size of both columnar and equiaxed regions was quite large. Furthermore, no evidence for nucleation of crystals on the side walls of the mold is discernible. This suggests that the heat flow was indeed uniaxial until the solid-liquid interface reached a height of 60 mm from the chill plate. Another notable feature was the nearly horizontal orientation of the thermocouple elements. This suggests that the momentum of the liquid metal during pouring did not cause the thermocouples to sag. Thus the temperature measurements truly correspond to the original elevations of the thermocouples from the copper chill.

The traces of all the eight thermocouples are shown in the form of temperature-time plots in Figure 19. The top four thermocouples along the centerline exhibit temperature horizontals at 645°C, the liquidus temperature of this alloy, whereas the remaining four thermocouples close to the chill plate do not show this behavior. Instead, they exhibit a small amount of temperature increase with time, due to the recalescence phenomenon. This can be attributed to the high solidification rates obtained at these locations which result in the release of latent heat in a relatively short duration. It is important to note that all the thermocouples showed the horizontal

at the eutectic temperature, namely 548°C. However, only the three thermocouples closest to the chill reveal the recalescence effects due to the eutectic reaction, $L \rightarrow \alpha + Al^2Cu$.

The predictions of the CAST-3 code along with experimental temperature-time data for another casting experiment (designed as Casting 202) are illustrated in Figure 20. The agreement between the model and experiment is excellent for the thermocouple closest to the chill plate (TC #1). For the other two thermocouples, the agreement is good at short times but at long durations, they deviate significantly. After 200 s, the error in predictions is 8-10%. This error observed at long solidification times is probably related to the uncertainty in the estimation of latent heat release in the equiaxed zone resulting from non-planar isotherms and solid-liquid interface.

The variation of copper content with distance away from the chill plate is shown in Figure 21. The copper content decreases gradually with distance up to about 50 mm (2.0 inches). These data are for Casting 207 and the columnar to equiaxed transition occurs at approximately 60 mm from the chill plate in this casting. Thus we can note that the continuous decrease in copper content with distance occurs only in the columnar zone; as the solid-liquid zone approaches the location where columnar to equiaxed transition occurs, the segregation profile changes drastically. This is due to the fact that the heat flow is strictly unidirectional only in the columnar growth zone and becomes multidirectional in the vicinity of the columnar to equiaxed transition (CET) zone. These experimental results obtained were verified by performing a duplicate experiment (Casting 202). Once again, the systematic decrease in the copper content persisted only in the columnar zone. The positive segregation observed in our experiments is consistent with the results reported by Flemings and Nero, and by Ohnanaka and Matsumoto.

The columnar to equiaxed transition during solidification of binary alloys has been studied by Flood and Hunt, Fredrickson and Osson, and Hunt. Hunt showed that the transition from columnar to equiaxed grains occurs when the temperature gradient in the liquid at the interface, G_L satisfied the following condition:

$$G_L = 0.617\, N_o^{1/3} \left\{ 1 - \left\{ \Delta T_N / \Delta T_c \right\}^3 \right\} \Delta T_c$$

where N_o is the density of nucleating sites, ΔT_n is the effective supercooling at the

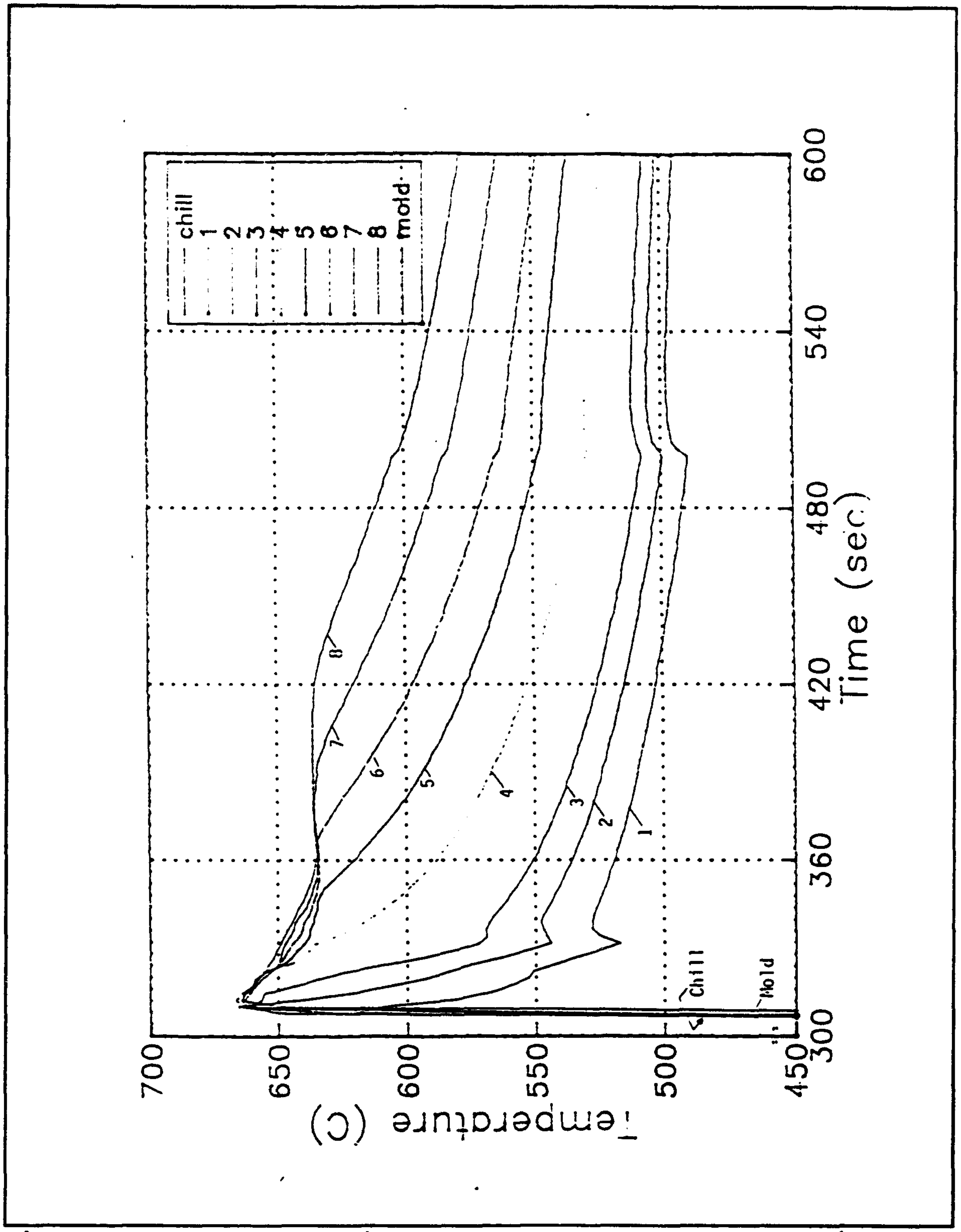

Figure 19: Temperature-time plots from thermocouples at different heights

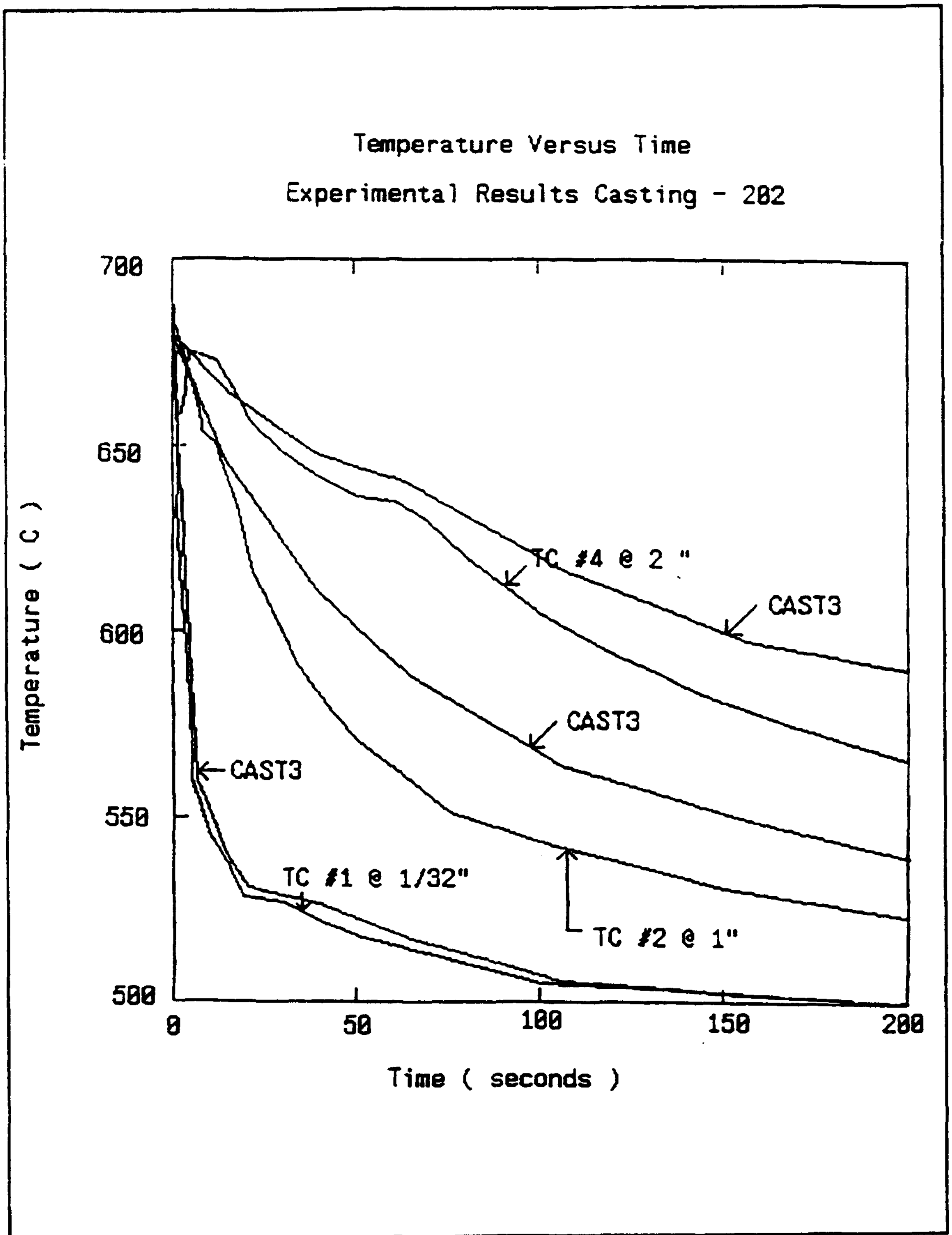

Figure 20: Predicted versus experimental temp-time plots

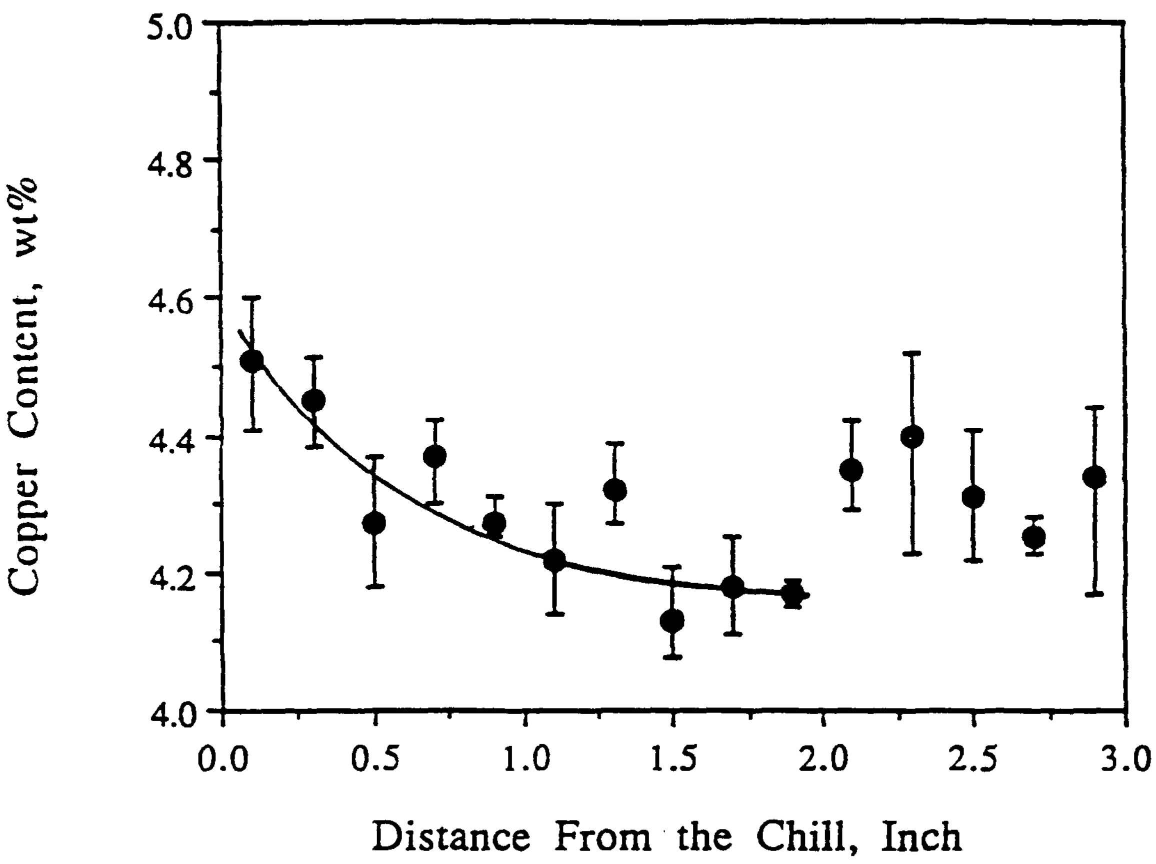

Figure 21: Plot of copper content vs distance from chill plate

nucleation sites and ΔT_c is the supercooling at the tip of dendrites.

The dendrite tip supercooling can be computed from a knowledge of the tip velocity and the alloy composition. Ziv and Weinberg have estimated that for an Al-3 wt%Cu alloy, the CET should occur at G_L = 0.070°C/mm. Thermal analysis data obtained in the current work yield a temperature gradient of 0.1°C/mm near the CET. Although this value is higher than that obtained by Ziv and Weinberg, it can be rationalized in terms of the composition difference. As copper content increases from 3 to 4.5 wt%, the critical temperature gradient also should increase gradually. Thus, the present experimental value of 0.1°C/mm for the critical temperature gradient is consistent with the theoretical prediction of the gradient at which columnar to equiaxed transition occurs.

2.4 Hot Extrusion Studies on a Cast γ-TiAl Alloy

The main objective of this task is to investigate the hot working behavior of a cast γ-TiAl alloy under typical ingot breakdown conditions, using both experimental and analytical methods. For this purpose, hot forward extrusion of solid, canned billets from cast ingots of a γ-TiAl alloy has been selected as a model problem. The specific roles played by preheat temperature, ram velocity, extrusion ratio, die geometry and can material in the evolution of the deformation substructures and the generation of extrusion defects have been examined.

In the initial phase of the program, the extrusion of round to round billets has been studied using cast and hot isostatically pressed (HIP) ingots of Ti-49.5Al-2.5Nb-1.1Mn alloy. A streamlined die with an extrusion ratio of 6:1 (true strain is 1.8) and a total length of 95.3 mm was used for this study. The ingots were electro-discharge machined to yield billets of 62.2 mm diameter and 133.4 mm length. These were sealed in evacuated cans (nominal thickness of 6.25 mm) made of type 304 stainless steel or CP-titanium. These preforms were coated with a glass lubricant, soaked at a constant temperature in the range 1050-1350°C for 2 hours and then extruded completely. The specific extrusion conditions are given below:

Table 2: TiAl round to round extrusion conditions

Temperature (°C)	Ram Velocity (mm/s)	Can Material
1050	15	304 Stainless
1150	15	304 Stainless
1150	44	304 Stainless
1250	15	CP-Titanium
1350	15	CP-Titanium

In addition, a partial extrusion was performed at 1150°C and 15 mm/s to obtain information on the flow patterns and also the variation of microstructure along the die length.

All the above extrusions were found to fracture at the nose region of the preforms, indicating that a modification in the preform design will be necessary to avoid this problem. Otherwise, the extrusions were found to be free from any type of internal/external defects. The failure near the nose region is related to the extensive thinning of the can, particularly CP-titanium. This in turn, can be attributed to the vast differences in the flow stress of values of γ-TiAl core and the stainless steel/titanium cans at the extrusion temperature.

Microstructural studies of these extrusions showed that dynamic recrystallization occurs extensively at all the extrusion temperatures and velocities. However, the resulting grain size exhibits strong dependence on both the extrusion parameters mention above. The grain size decreased from the center toward the surface on the TiAl extrudate systematically. In order to interpret these observations meaningfully, it was essential to determine the local values of temperature, strain and strain rate under steady state extrusion conditions. A coupled (deformation and thermal) finite element method (FEM) study was performed to determine the special and temporal distributions of the above parameters during extrusion.

The above experiments in which the billets were completely extruded yielded valuable information on the plastic flow behavior as well as the microstructural features associated with the steady state extrusion conditions. In contrast, the transient or dynamic response during extrusion was investigated through another set of experiments in which the billets were partially extruded and removed from the extrusion container/die as quickly as possible. The transverse and longitudinal variations in the microstructure observed in these partially extruded specimens enabled us to correlate the distributions in temperature, strain and strain rate obtained from the analytical modeling work with microstructural parameters such as the fraction recrystallized and the mean (recrystallized) grain size.

The second phase of this program consists of experiments designed to bring out the influence of stress state on the microstructure and deformation behavior of 3-Dimensional shapes. For this purpose, extrusion of rectangular geometry was chosen and experiments were performed with a special emphasis on the effect of aspect ratio (width/thickness) of the rectangle. Specially designed dies corresponding to a constant extrusion ratio of 6:1 with aspect ratios varying from 1 to 6, were fabricated, heat treated and surface coated. Seven different extrusions were performed using these dies as per the details given below:

Table 3: TiAl round to rectangular extrusion conditions

Temperature (°C)	Aspect Ratio	Can Material	Velocity (mm/s)
1150	1:1	304 Stainless	29
1150	2:1	304 Stainless	38
1150	4:1	304 Stainless	38
1150	6:1	304 Stainless	38
1350	1:1	CP-Titanium	43
1350	2:1	CP-Titanium	43
1350	6:1	CP-Titanium	43

All the extrusions were successful and contained no macro-defects other than cracking/fracture near the nose regions. Optical metallography and detailed NDE of these extrudates were performed. Furthermore, finite element analysis using ALPID 2-D and ALPID 3-D codes was performed to predict the distributions of field variables such as strain, strain rate, temperature and effective stress/mean stress ratio. These quantities were correlated with the microstructural characteristics in order to assess the influence of the die geometry and the stress state on microstructural evaluation, during rectangular extrusion.

2.5 Canned Extrusion of TiAl with Core Insulation

Nonisothermal forward extrusions of cast γ-TiAl (Ti-49.5Al-2.5Nb-1.1Mn, at%) and cast IN100 were performed. Past experience and finite element analysis indicate that rapid heat loss occurs from the canned billet to the die during the extrusion process. The temperature gradient in the billet produces nonuniform microstructure. A technique was developed to insulate the billet with layers of a 1.27 mm thick silica fabric, known commercially as Siltemp and manufactured by the Haveg Division of Ametek. The usual canning technique is followed except that an allowance for the fabric is machined in both the can and the billet. The fabric is then wrapped around the billet and on both ends, sealed in the can and evacuated.

The first extrusions using this technique were cast IN100 billets with the extrusion numbers of 11121 and 11131. The billets were canned in 304 stainless steel, heated to 1205°C, and extruded through a 6:1 area reduction round geometry streamlined die at 260°C with a ram velocity of 12.7 mm/s. Extrusion #11131 differed only in that two layers of Siltemp were used in place of one.

The cast γ-TiAl alloy (Ti-49.5Al-2.5Nb-1.1Mn) was canned in 304 stainless steel in the same manner and extruded with billet temperatures of 1050, 1150, and 1225°C and a die and container temperature of 260°C as reported in Goetz, el al. ["Effect of Core Insulation on the Quality of the Extrudate in Canned Extrusions of γ-Titanium Aluminide," J. of Materials Proc. Techn., 35(1992), pp. 37-60.]. A 6:1 reduction round streamline die was used here as well. The extrusion numbers were as follows; 11165, 1225°C, 16.25mm/s; 11271, 1150°C, 15.0mm/s; 11273, 1050°C, 10.7mm/s. In addition to the previous three extrusions, this alloy was heated to 1200°C for 2 hours followed by 1 hour at 1375°C, and extruded through a 6:1 streamline die (Extrusion #11347). This extrusion was an attempt to test the feasibility of extruding TiAl's at such a high temperature with 304 stainless steel instead of the CpTi cans typically used at this temperature. In addition to insulating the TiAl billet, two layers of Siltemp were used to avoid a eutectic reaction between the stainless steel can and TiAl, thereby allowing the use of a can with a higher flow stress than CpTi.

This work was conducted in cooperation with R.L. Goetz of UES, INC. who was supported under Contract No. F33615-89-C-5604, V.K. Jain of the University of Dayton and Edison Materials Technology Center, Dayton, Ohio, and C.M. Lombard of WL/MLLN.

2.6 Visioplasticity Study of 6061 Aluminum

In this task, a visioplasticity experiment was conducted for the purpose of evaluating the accuracy of the results of the 3-D finite element code ANTARES.

Analytical models that simulate deformation of materials must be thoroughly validated before their results can be applied with confidence. The Processing Lab, which provides access to both pilot plant scale equipment and the latest in simulation models, is uniquely capable of conducting such validation studies.

The current generation of simulation models attack the problem of true 3-dimensional plastic flow with heat transfer. A validation problem must be complex enough to exercise the model features being examined, yet simple enough to allow for adequate evaluation of the models accuracy.

The geometry selected for this task was a cube 1.5" on each side with a single eccentric hole of 0.25" diameter drilled through 0.50" from the center of one edge. This block was upset with the hole parallel to the upper platten, so that the hole would close upon itself during deformation. The material selected was 6061 T6 Aluminum.

Several experiments were performed in which the block was upset at elevated temperature against cold dies. The process was simulated using the ANTARES software.

It is critical for a validation study that the load and stroke be recorded during the actual forming operation. The 500-ton Lombard press was not fully instrumented, so the components required for load and stroke recording were selected and purchased. The completion of this study was interrupted by the laboratory relocation from Building 32 to 51. Building utilities to the old lab were unexpectedly cut by WPAFB Civil Engineering and could not be restored.

It is planned that this study and others like it will be conducted on the new 1000-ton Erie forge press in Building 655. That press will be fully instrumented and its higher tonnage will permit the use of larger specimens.

2.7 Cold Rolling of Bi-based High Temperature Superconducting Tape

The goal of this task was to form a superconducting oxide ceramic tape by packing Bi-based powders into silver tubes and reducing them to tape form by rolling. This was a collaborative effort in support of superconductor research being performed by WPAFB, University of Dayton Research Institute and Wichita State University. The overall goal of that research was to optimize the transport critical current density of the Bi-based tapes.

Oxide ceramic powder (specifically Bi-Pb-Sr-Ca-Cu-O) that had been calcined under several different conditions, was loaded into silver tubes with O.D. = 6.35mm and I.D. = 4.35mm. The tube ends were crimped and sealed. The powder-in-tube was cold rolled (up to 66 passes) to form a tape approximately 1.2 cm wide and up to 20 cm long. After rolling, the super conducting properties of the tapes were evaluated. A total of 11 samples were prepared and formed into tape by multi-pass rolling operations.

Complete details on this work are contained in "Bi-Based High Temperature Superconducting Tapes by Cold Rolling Method" by Kozlowski, Oberly, Maartense, Leese, Ho Barker, Jones and Brown, IEEE Transactions on Magnetics, Vol. 27, 1991, p.890.

2.8 Die Design and Process Modeling for $Mg+B_4C$ Alloy Extrusion

The goal of this task was to investigate potential processing conditions for the extrusion of $Mg+B_4C$ alloy. Computer aided die design and process modeling was employed, rather than going straight to the shop floor and conducting a trial and error program. Five conditions were considered for extrusion of $Mg+B_4C$ alloy. The three lower strain rates were quickly discarded for realistically extruding, since the die velocity would be so low as to require inordinately long residence time of the hot billet in the container. The two highest strain rates were, therefore, selected, and die and process design performed using Xtruder for a 4:1 reduction ratio. The designed process was then modeled as an isothermal axisymmetric case using MME-ALPID. The process conditions for the model were as follows:

Case 1: 850°F, nominal strain rate $10^{-1.5}$ per second, 4:1 reduction ratio

Case 2: 950°F, nominal strain rate of 10^{0} per second, 4:1 reduction ratio

A few of the results for case 1 are given here. Complete results for both cases were submitted in a monthly report on this contract and are also available in the Processing Lab office.

The flow stress data for the alloy is depicted in Figure 22. The round-to-round extrusion die that was designed for the 700-ton Lombard extrusion press is shown in Figure 23. The strain rate and strain distributions in the die for Case 1 are shown in Figures 24 and 25, respectively.

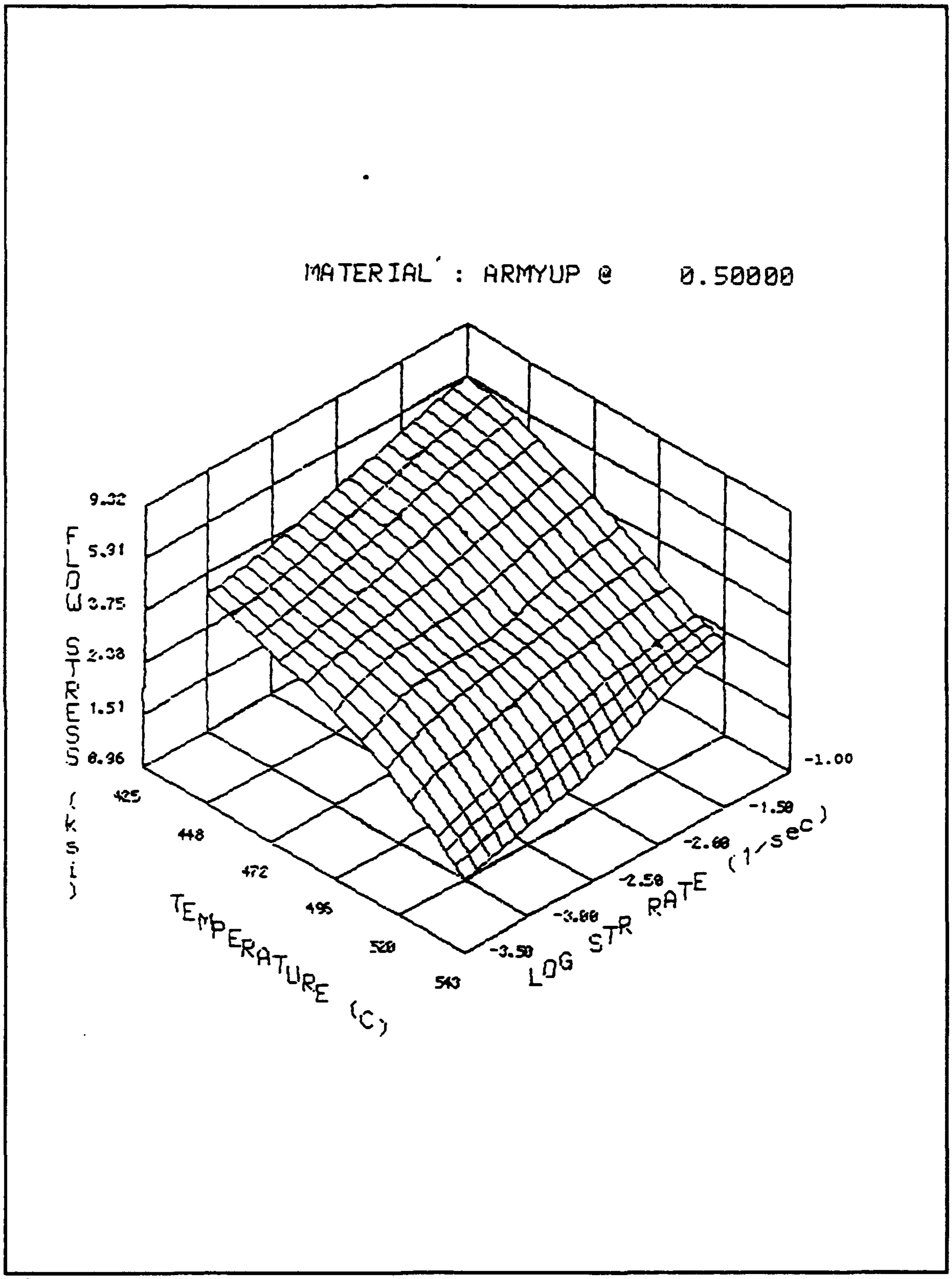

Figure 22: Plot of flow stress

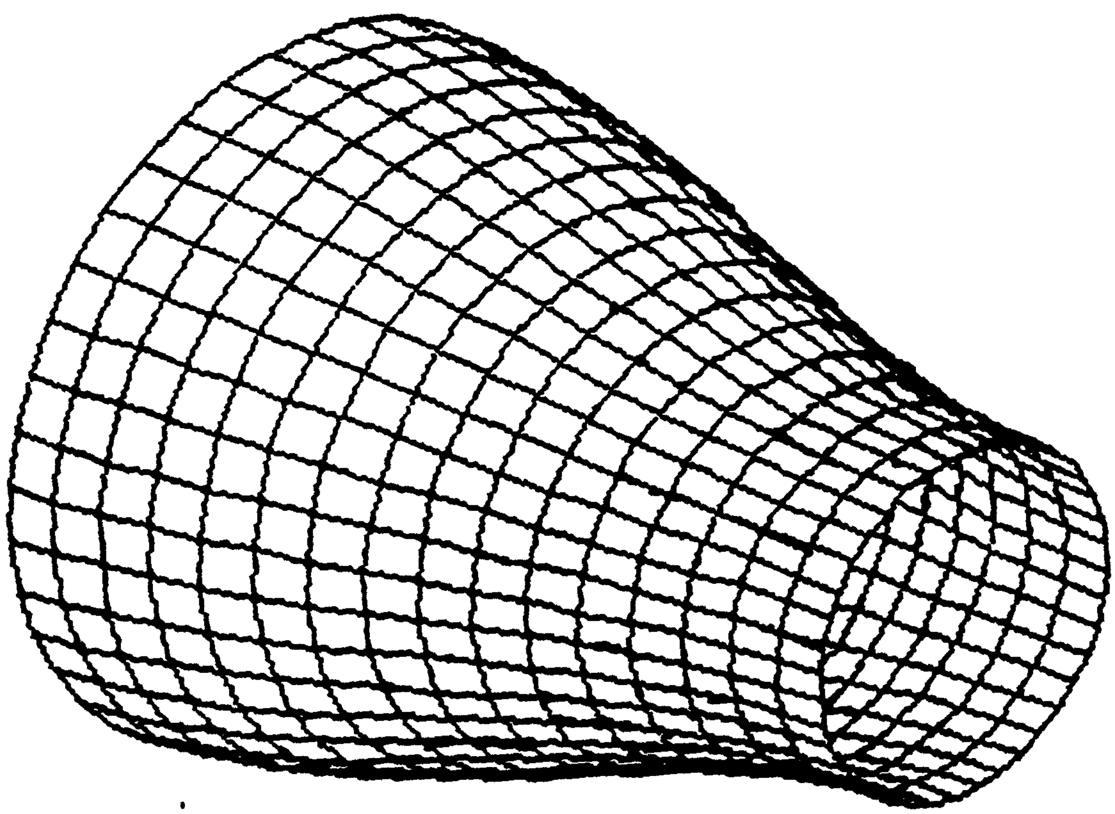

Figure 23: 3-D depiction of die design

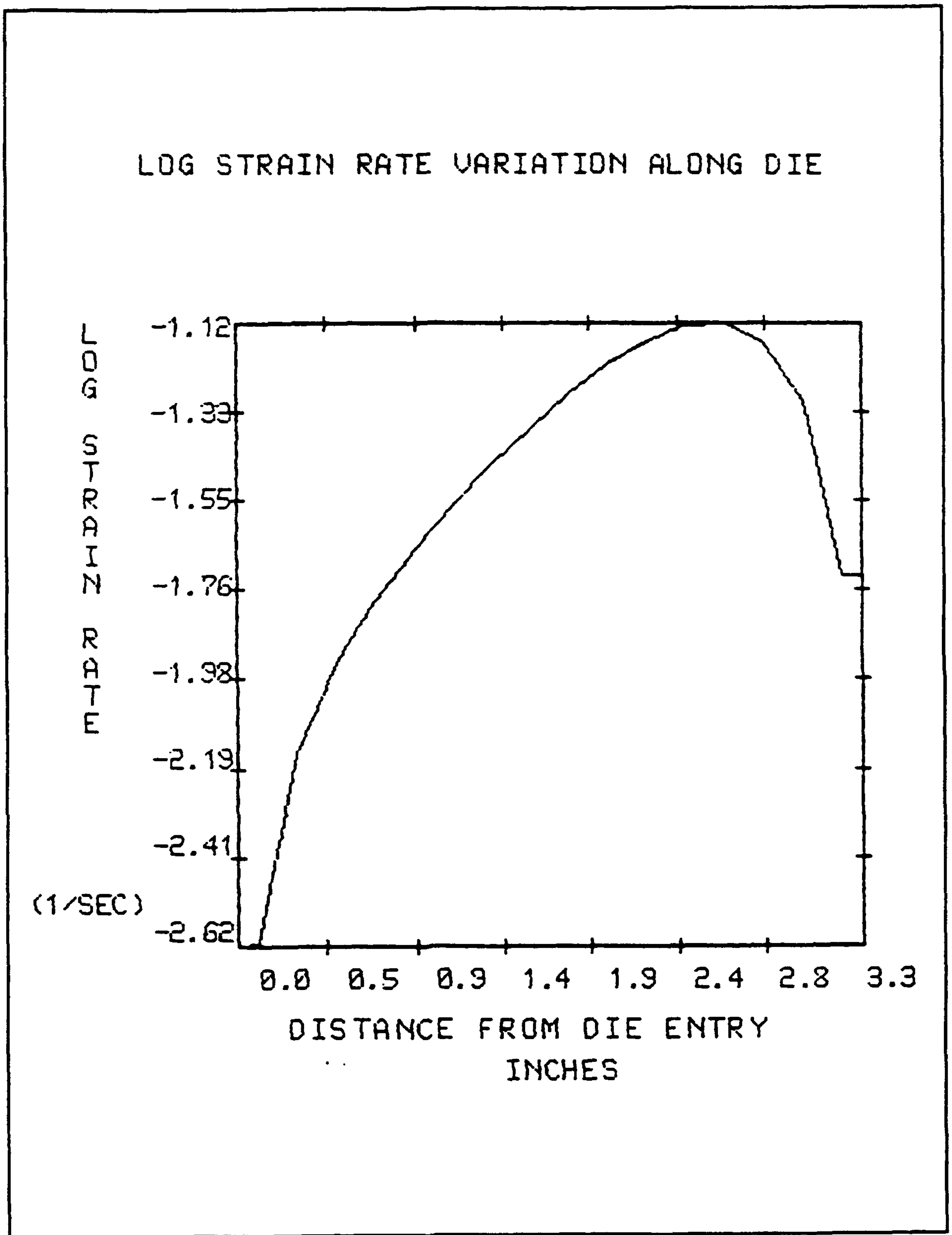

Figure 24: Strain rate variation along the die

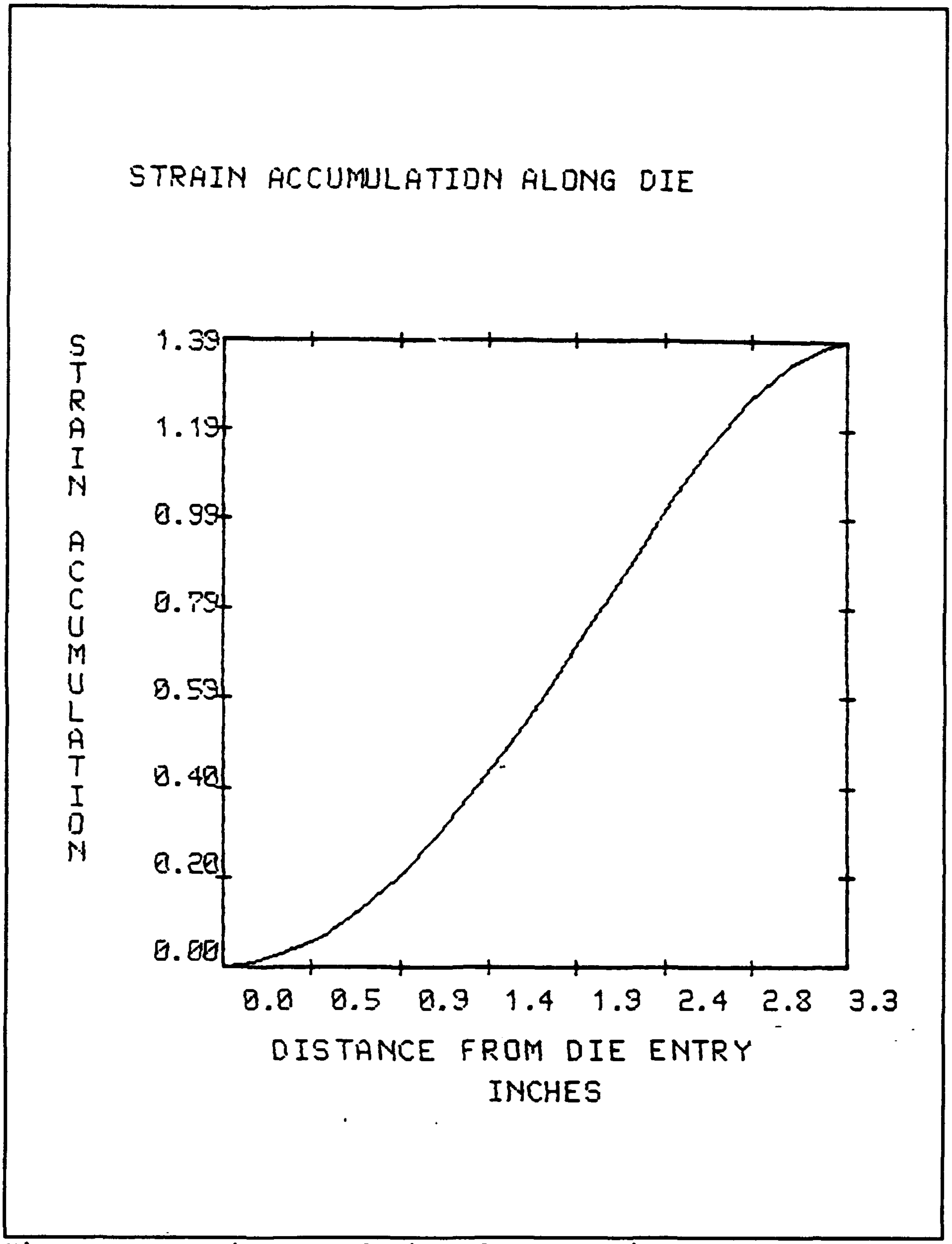

Figure 25: Strain accumulation along the die

3. PROCESSING OF MATERIALS

Aside from the laboratory relocation, most of the day-to-day activity under this program was focused on the actual processing of materials by either deformation or solidification. This work supported the contractual effort research activities as well as the activities of numerous other agencies both inside and outside of the government. Summaries of these processing operations are given in the following subsections. More detailed listings of the major operations are given in the appendices. Complete records were maintained on every major operation performed and are kept on file in the Processing Lab office. Sample record sheets are shown in Appendices A-E.

3.1 Extrusion

The 700-ton Lombard extrusion press was the most heavily used piece of equipment in the lab. Despite the work slowdown and stoppage caused by the lab relocation, 742 extrusions were performed under this program. Customers included several groups in Wright Laboratory, as well as a dozen private corporations. Table 4 gives a breakdown of the extrusions performed cross tabulated by Agency versus Material. Table 5 shows Agency versus die type. Appendix A gives a complete listing of all the extrusion operations performed.

Table 4: Summary of Extrusion Operations by Material Class

Source Agency	Material Class															Total
	Al	Co	Cu	FeAl	IR&D	Mg	Mo	Nb	Ni	NiAl	SS	Ti	TiAl	W	Y	Number
Allison-Campbell	0	0	0	0	0	0	0	0	0	0	0	0	14	0	0	14
Case Western	0	0	0	0	0	0	0	0	0	28	0	0	0	0	0	28
Garrett Corp	0	0	0	0	0	0	0	0	0	0	0	0	13	0	0	13
GE/Evendale	0	0	0	0	0	0	0	0	36	0	0	53	90	0	0	179
Illinois Institute	0	0	0	0	0	0	0	0	0	6	0	0	0	0	0	6
Lockheed	0	0	0	0	0	4	0	0	0	0	0	0	0	0	0	4
Martin Marietta	0	0	4	2	3	0	0	4	0	0	0	0	20	0	0	33
McDonnell Douglas	9	0	0	0	0	0	0	0	0	0	0	17	80	0	0	106
Metcut	0	0	0	0	0	0	0	0	0	0	0	2	28	0	0	30
Pratt & Whitney	0	0	0	0	0	0	0	0	0	2	0	0	51	0	0	53
SPS Technologies	0	10	0	0	0	0	0	0	0	0	0	0	0	0	0	10
UD	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1
UES	17	0	0	0	0	0	2	16	8	2	2	14	52	0	0	113
Westinghouse	0	0	0	0	0	0	0	3	0	0	0	0	0	33	0	36
WL/MLLM	10	0	0	0	0	0	0	0	0	0	0	0	1	0	0	11
WL/MLLN	8	0	0	0	0	0	0	0	0	0	0	12	1	0	0	21
WRDC/MLLM	26	0	0	0	0	0	5	0	2	0	2	0	9	0	0	44
WRDC/MLLN	9	0	0	0	0	0	0	2	0	0	1	16	5	0	0	33
WRDC/MLLS	0	0	0	0	0	0	0	0	0	0	0	0	4	0	0	4
WRDC/POOX-3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1
Wright State Univ	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	2
Total Number	79	10	4	2	3	4	7	27	46	38	5	114	369	33	1	742

Table 5: Summary of Extrusion Operations by Die Type

Source Agency	Die Type 32°	41°	45°	60°	90°	Streamline	Total Number
Allison-Campbell	0	0	0	7	0	7	14
Case Western	0	0	0	28	0	0	28
Garrett Corp	0	0	0	2	0	11	13
GE/Evendale	0	0	33	130	0	16	179
Illinois Institute	0	0	0	6	0	0	6
Lockheed	0	0	0	0	4	0	4
Martin Marietta	0	0	0	15	0	18	33
McDonnell Douglas	0	0	5	97	4	0	106
Metcut	0	0	3	5	3	19	30
Pratt & Whitney	0	0	3	24	0	26	53
SPS Technologies	0	0	0	0	0	10	10
UD	0	0	0	0	0	1	1
UES	1	2	0	34	3	73	113
Westinghouse	0	0	0	20	7	9	36
WL/MLLM	0	0	5	5	0	1	11
WL/MLLN	0	0	0	1	7	13	21
WRDC/MLLM	0	0	10	21	5	8	44
WRDC/MLLN	0	0	6	7	5	15	33
WRDC/MLLS	0	0	0	1	0	3	4
WRDC/POOX-3	0	0	0	1	0	0	1
Wright State Univ	0	0	0	2	0	0	2
Total Number	1	2	65	406	38	230	742

3.2 Evacuation and Degassing

A total of 493 evacuation, degassing and sealing operations were performed on extrusion, forge, heat treatment, HIP and rolling cans. Summaries of these operations by Material Class and by Type of Can are given in Tables 6 and 7, respectively. A complete list of these operations is given in Appendix B. Detailed records of each operations are on file in the Processing Lab office.

Table 6: Summary of Evacuation Operations by Material Class

	Material Class											Total
Source Agency		Al	CRGA	Cu	Mg	MoSi2	Nb	Ni	NiAl	Ti	TiAl	Number
Allison	0	0	0	0	0	0	0	0	0	0	14	14
Garrett	0	0	0	0	0	0	0	0	0	0	13	13
Illinois Institute	0	0	0	0	0	0	0	0	2	0	4	6
Lockheed	0	0	0	0	4	0	0	0	0	0	0	4
Martin Marietta	0	0	0	4	0	0	0	0	0	0	15	19
McDonnell Douglas	0	5	0	0	0	0	0	0	0	17	76	98
Metcut	14	1	4	0	0	0	2	0	0	102	86	209
MLBT	10	0	0	0	0	0	0	0	0	0	0	10
MLLM	0	9	0	0	0	1	0	0	0	19	12	41
MLLS	0	0	0	0	0	0	0	0	0	0	4	4
UES	1	1	0	0	0	2	6	6	0	0	57	73
WRDC/POOX-3	0	0	0	0	0	0	0	2	0	0	0	2
Total Number	25	16	4	4	4	3	8	8	2	138	281	493

Table 7: Summary of Evacuation Operations by Type of Can

Source Agency	Can Type: Extrusion	Forge	Heat Treat	HIP	Rolling	Total Number
Allison	14	0	0	0	0	14
Garrett	13	0	0	0	0	13
Illinois Institute	6	0	0	0	0	6
Lockheed	4	0	0	0	0	4
Martin Marietta	19	0	0	0	0	19
McDonnell Douglas	98	0	0	0	0	98
Metcut	31	12	0	166	0	209
MLBT	0	0	0	10	0	10
MLLM	22	0	3	16	0	41
MLLS	4	0	0	0	0	4
UES	52	0	21	0	0	73
WRDC/POOX-3	0	0	0	0	2	2
Total Number	263	12	24	192	2	493

3.3 Vacuum Arc Melting (Button Melts)

A total of 906 Vacuum Arc Melting operations were performed primarily in support of alloy development work by Government and Contract scientists in the Wright Laboratory. These were mainly 50 to 250 gram button and cigar melts. Table 8 summarizes these operations by material class and customer. A complete list of the operations is given in Appendix C. Detailed records are on file in the Processing Lab office.

Table 8: Summary of Vacuum Arc Melt Operations by Material Class

	Source Agency								Total
Material Class	Metcut	MLLM	MLLN	MLLS	SRL	UDRI	UES	WSU	number
Al	1	21	0	0	0	2	25	0	49
Cr	0	40	0	0	0	0	30	0	70
Fe	0	0	0	0	0	0	1	3	4
Hf	0	1	0	0	0	0	0	0	1
Mn	0	0	0	0	0	0	4	0	4
Mo	4	17	0	0	0	0	27	0	48
Nb	0	13	0	0	2	0	208	0	223
Ni	0	1	0	0	0	0	20	0	21
NiAl	9	45	0	0	0	0	50	0	104
Si	0	0	0	0	0	0	11	0	11
Ta	0	8	0	0	0	0	0	0	8
Ti	3	55	0	4	0	0	25	0	87
TiAl	122	29	3	21	30	0	29	16	250
V	0	0	0	0	0	0	6	0	6
W	0	2	0	0	0	0	16	0	18
Y	0	0	0	0	0	0	1	0	1
Zr	0	1	0	0	0	0	0	0	1
Total number	139	233	3	25	32	2	453	19	906

3.4 Vacuum Induction Melting (VIM)

A total of 38 Vacuum Induction Melts (VIM) were performed. These were all conducted for solidification research. Many were instrumented with multiple thermocouples so that cooling curves could be compared to results of simulation modeling. The VIM furnace was unavailable for much of the contract effort due to a PCB spill that contaminated the induction generator. Table 9 summarizes these operations. A complete list of the operations is given in Appendix D. Detailed records are on file in the Processing Lab office.

Table 9: Summary of Vacuum Induction Melting Operations

Charge Material Class	Source Agency: Ohio State Univ.	Source Agency: UES	Total number
Al	4	22	26
Steel	0	12	12
Total number	4	34	38

3.5 Forging

The 500-ton Lombard forge press was used for plasticity studies, ring compression tests and simple upsettings. This press was scrapped when the new 1000-ton Erie press was procured for installation in the new laboratory. Table 10 summarizes the forging work. A complete list of the operations is given in Appendix E. Detailed records are on file in the Processing Lab office.

Table 10: Summary of Forging Operations by Material Class

	Material Class							
Source	Ag	Al	Ni	NiAl	SS	Ti	TiAl	Total Number
Metcut	0	0	0	0	0	0	14	14
UES	0	16	0	6	0	12	2	36
WL/POOX-3	4	0	0	0	6	0	0	10
WRDC/MLLM	0	13	57	0	0	20	0	90
Total Number	4	29	57	6	6	32	16	150

3.6 Rolling

A total of 28 multipass rolling operations were performed. These were in support of two projects: (1) the rolling of a ceramic superconducting tape; and (2) pack rolling of TiAl. Table 11 summarizes the operations. Detailed records are on file in the Processing Lab office.

Table 11: Summary of Rolling Operations by Material Class

Source	Ag	TiAl	Al-Cu	Total Number
WL/POOX-3	11	0	0	11
WRDC/MLLN	0	2	0	2
MetCut	0	3	0	3
GE	0	6	0	6
OSU	0	0	6	6
Total Number	11	11	6	28

(Columns Ag, TiAl, Al-Cu under the heading "Material Class".)

3.7 Heat Treatment

Nearly all of the hundreds of extrusion, forging and rolling operations that were performed required preheats to bring the billets up to the working temperature. In addition to these preheat operations, there were 131 heat treatments performed that were not direct precursors to forming operations. These included:

Table 12: Summary of Heat Treatments

Type of Specimen	Number of Operations
Ring compression specimens	22
Extrusion billets	58
Metallography specimens	51
Total number	131

3.8 Welding and Fabrication

Welding and fabrication operations were performed in support of metal working operations and equipment maintenance. The bulk of the machining and welding is the making of vacuum tight cans that contain either powder or solid research materials to be extruded, rolled, forged or HIP'ed. Cans are fabricated from a variety of materials, most commonly titanium, stainless steel, carbon steel, or aluminum. Exotic materials and welds are occasionally required, such as the welding of C.P. titanium to TiAl. Every can that is fabricated is tested for vacuum tightness using a helium leak detector. Summaries of the major welding and machining operations are given in Tables 13 and 14, respectively.

Table 13: Summary of Welding Operations

Type of Welding Operation	Number of Operations
Extrusion cans	217
Hot Isostatic Press cans	165
Vacuum Hot Press cans	67
Heat Treatment cans	21
Other welding tasks	86

Total number	556

Table 14: Summary of Machining Operations

Type of Operation	Number of Operations
Extrusion billets	102
Extrusion cans	77
Hot Isostatic Press cans	20
Heat Treatment cans	7
Forging billets	8
Misc billet machine/cut	88

Total number	302

4. RELOCATION AND MODERNIZATION OF LABORATORY

Under this contract, the Experimental Materials Processing Laboratory was moved from its original location in Buildings 32 and 51 to Building 655. This move was also taken as an opportunity to upgrade major laboratory equipment.

The "Foundry" had been located in Building 51 since its construction during the era of the Wright Brothers. It was originally focused on metal casting. During the 1950s, most of the melting furnaces were removed, and the lab was redirected toward metal deformation processing with the acquisition of extrusion, forge and mechanical presses as well as a rolling mill and swager. This equipment has been heavily used in the past 35 years to support the research and development work of both the Air Force and private U.S. industries.

In the 1980s, the Air Force Materials Laboratory consolidated most of its operations into Building 655. This building was designed with a large, central high bay to eventually accommodate the heavy equipment of the Processing Lab.

A major effort under this program was to accomplish the actual relocation of the Processing Lab. During the first 2 years of the contract, planning and preparation for the move were carried out concurrently with ongoing operations. The new lab space was designed and modified, equipment and materials were prepared for the move, turned in, or disposed of, and arrangements were made to modernize the extrusion press and to replace the forge press. The welding and metalography labs in Building 32 were temporarily relocated to Building 51 and then the major relocation from Building 51 to 655 was accomplished.

The major steps in the relocation and modernization of the laboratory are discussed in the following subsections.

4.1 Building 655 High Bay Modifications

The High Bay in Building 655 required substantial modifications to accommodate the Processing Lab. The actual engineering design work and construction were carried out by outside contractors under the direction of WPAFB Civil Engineering. UES personnel worked closely with both Government engineers and contractor personnel to assist and advise in both the design and construction stages. As operator of the existing and future equipment, UES was called upon to define all of the detailed requirements in terms of power, water, ventilation,

floorspace and working floorplan.

Major changes to the High Bay included:

1. Adding more electric power to handle the heavy press pump motors.
2. Running electric, water and compressed air lines to all equipment locations.
3. Isolating the room from the rest of the building air conditioning and ventilation system in order to contain dust and dirt.
4. Adding numerous high volume fume hoods to remove heat, fumes and dust.
5. Adding an air handler system to provide make-up air.
6. Preparing concrete foundations for the extrusion and forge presses.
7. Building a mezzanine at one end of the bay for offices.
8. Building a sound proof pump room for the press pump systems.

Most of the changes were completed by the end of 1991.

4.2 Move from Building 32 to Building 51

At start of this program, the weld lab, metallography lab and metals storage were in Building 32. That building had to be vacated several months prior to the scheduled move to Building 655. Welding is a critical capability to ongoing operations, so the welding equipment was moved and setup temporarily in Building 51. The metallography lab was not as critical, so its equipment was turned in to the Government. The remaining equipment and materials from Building 32 were temporarily stored, disposed of, or turned in to the Government. Many old chemicals, left over from when the Materials Lab occupied most of Building 32, presented a disposal problem. These included many hazardous materials that had been left in the building by prior users, even including radioactive and explosive compounds.

4.3 Move from Building 51 to Building 655

The major relocation of the Processing Lab was accomplished under this contract by UES personnel with the subcontracted assistance of Muth Brothers (riggers), PDQ (electricians) and Donnell (plumbers). In the last few months of 1991, UES sorted through the equipment and materials in Building 51. A staged shutdown and disconnect of equipment was accomplished

that kept the most critical operations still running up to the last possible moment. Research operations were still being performed concurrent with the shutdown while electricians and plumbers were disconnecting nonessential equipment and UES technicians prepared equipment and materials for transport. The extrusion press was the last piece of equipment to be shut down. The last extrusion to be performed in Building 51 was in October 1991.

The transportation of equipment and materials to the new lab in Building 655 was accomplished Blitzkrieg style, in just 3 weeks in December 1991. Meanwhile, the extrusion press was disassembled and shipped back to the manufacturer for modernization.

Setting up the new Processing Lab went very smoothly, thanks to careful planning. Termination points for water, air and power lines were already in place close to equipment locations. Reconnection was straightforward.

A substantial delay occurred when getting permission from Civil Engineering to actually turn on the equipment in the High Bay. The contract under which the High Bay modification had been performed was not accepted due to problems with power and ventilation that required additional work. Although frustrating at the time, this delay did not adversely affect getting the Processing Lab back into operation. Equipment maintenance and repair as well as many other move-in chores were completed in the time before equipment start up was authorized.

The major milestones in the relocation and modernization of the Processing Lab are shown in Table 15. The new laboratory was fully operational in November 1992.

Table 15: Laboratory Relocation Milestones

MAY 90	Final drawings for new lab approved
NOV 90	Building modifications for new lab begun
OCT 91	Equipment disconnect from Bldg. 51 begun
NOV 91	Building modifications complete
DEC 91	Extrusion Press removed from Bldg. 51 for modernization
DEC 91	Move of equipment from Bldg. 51 to Bldg. 655
JAN 92	Equipment hook-up initialized in Bldg. 655
MAR 92	New 1000-Ton Forge Press delivered
MAY 92	Modernized Extrusion Press delivered

AUG 92	Forge Press operational and tested out using Erie Press tooling
OCT 92	Extrusion Press operational and tested out
OCT 92	New conventional tooling installed in Forge Press
OCT 92	New isothermal tooling system designed for Forge Press
OCT 92	New laboratory dedicated
NOV 92	New laboratory fully operational
NOV 92	First research billet extruded
JAN 93	First research forging

4.4 Modernization of 700-Ton Extrusion Press

The Lombard extrusion press was removed from Building 51, upgraded by the manufacturer and installed in Building 655 as a part of the contractual effort under this program.

The extrusion press has been the real workhorse of the Processing Lab over the last 35 years. However, the hand-operated control valves and water based accumulator system had finally become outdated. The lack of precise controls and complete data acquisition had become a stumbling block to more advanced research tasks. It was decided that the press would be stripped down to its basic frame and rebuilt with an advanced drive and control system.

The work was divided into two distinct parts. First, the engineering design, detailing and material and component specifications were accomplished in mid-1991, prior to the relocation of the Processing Lab. Second, the press was removed to Youngstown, Ohio, where the actual modifications were performed. The modifications consisted of:

I. Press Proper
   a. New double acting oil hydraulic pull-back cylinders.
   b. New double acting oil hydraulic container shifter cylinders designed for 5000 psi operating services as required to increase container sealing force.
   c. New redesigned container housing with provisions for top guiding in addition to the existing bottom guide system.
   d. New 1000°F container heating system with controls.
   e. New crosshead and container housing guide bushings.
   f. New oil compatible main cylinder packing.

II. New Hydraulic Power Unit
   a. New surge valve and mounting attachments to main cylinder.
   b. New press piping from hydraulic power unit to all cylinders on the press.
   c. New self-contained, direct pumping oil hydraulic power unit, capable of providing controlled hydraulic power for all operational functions of the press in accordance with parameters outlined below.

Press strokes:

Maximum crosshead stroke	31"
Maximum extrusion stroke	15"

Maximum billet container stroke 12"

Press speeds:

Rapid advance variable to 580 ipm

Pressing (extrude) variable from 0.1 to 240 ipm

Rapid return variable to 740 ipm

System Operating Pressure:

Main hydraulic system 3000 psi

Container sealing 5000 psi

III. Electrical and Control:

a. New pump drive motors.

b. New motor control center.

c. New logic control center and operator's station having the capabilities of later upgrade to computer programmable control of all functions of the press and having the following design features:

1. Control ram speed manually or programmed control from 0.1 to 240 ipm pressing speed.
2. Specify desired ram velocity or load profile profile.
3. Specify load and stroke limits.

4.5 Acquisition of 1000-Ton Forge Press

The old 500-ton Lombard forge press in Building 51 was replaced with a new 1000-ton Forge Press acquired by the Government directly from Erie Press Systems. UES personnel, as the press operators, assisted with the technical aspects of the procurement and worked closely with Erie Press Systems during press installation and test out.

There were several reasons behind the Government decision to replace the 500-ton forge press. First, the 500-ton load capacity was too low; there were numerous times when a greater capacity was needed. This was often the case when pressing extremely high flow stress materials. A greater capacity is also required when working with large grain size materials, since the specimen size cannot be reduced. Second, the old control system was also inadequate. Load control could not be programmed at all. In one case in 1990, the die stack was seriously damaged when a specimen flow stress was higher than expected. Third, the daylight and platten area on the old press were too small to install a fully functional environmental chamber for isothermal forging.

The new 1000-ton Erie forge press has an oil hydraulic plus nitrogen drive system that is fully computer controlled with data acquisition of all critical parameters. The key specifications are:

Pressing Capacity	1000 Tons
Pullback Capacity	150 Tons
Platen Area (L-R x F-B)	60" x 60"
Top and Bottom Bolsters Thickness	6"
Daylight Between Bolsters	72"
Main Ram Stroke	15"
Main Ram Diameter	26"
Pullback Ram Diameter (2)	10" x 5-1/2"
Ejector Capacity	50 Tons
Ejector Stroke	3"
Ejector Ram Diameter	7" x 3-1/2"
Cushion Capacity	250 Tons
Cushion Area (L-R x F-B)	36" x 36"
Cushion Stroke	10"
Cushion Ram Diameter	26"

Press Operating Speeds

Advance	5"/Sec.
Fast Press (4" working stroke)	5"/Sec.
Slow Press	.001-.5"/Sec.
Return	5"/Sec.
Ejector Extend	5"/Sec.
Ejector Retract	5"/Sec.
Cushion up	.5"/Sec.

5. EQUIPMENT AND OPERATING PROCEDURE IMPROVEMENTS

During the course of this program, many improvements were made to existing equipment and operating procedures. Among the most significant was the greater use of computers for data acquisition and for data management.

5.1 Computerized Database of Extrusion, Melting and Evacuation Records

One of the great assets of the Processing Lab is the decades of experience that has been gained in processing of everything from simple aluminum to superalloys to refractory metals. The details of past operations are stored in filing cabinets full of paper records. Drawing on this experience base is dependent on a scientist or technician recalling from memory that, for example, a particular alloy was extruded in the late 1970s. Then a manual search of the records from that period is conducted.

Under this program, a computerized database system was developed for the extrusion, melting and evacuation records. The primary design criteria for the system was that information typed in today would never be lost due to the obsolescence of any particular computer or software package. For this reason, it was decided to use a popular, commercial, PC based database package to develop the system. Ashton-Tate dBase IV was selected. This has the advantage that a huge customer base assures that the software package will continue to be updated to new computer systems and printers. Also, many other commercial software packages can directly import dBase formatted files.

This computerized database was used to enter and print all of the extrusion records during this program. A sample extrusion record is shown in Figure 26.

AIR FORCE MATERIALS LABORATORY
EXPERIMENTAL MATERIALS PROCESSING LABORATORY
WRIGHT PATTERSON AIR FORCE BASE, OHIO

DATE: 04/19/90	EXTRUSION NUMBER: 11121
SOURCE: UES (Bob Goetz)	
BILLET COMPOSITION: IN-100	
ALLOY SYSTEM: Ni-Base	
BILLET DIA: 2.870	BILLET LENGTH: 7"
BILLET NOSE: .500 45Deg	BILLET JACKET: S.S.
BILLET ID. NO. ----------	BILLET WT: -------------
CONTAINER TEMP: 500	CARBON BLOCK: 4"
CONTAINER SIZE: 3.072	STEEL BLOCK: ---------
CONTAINER LINER NO: 931	
DIE RATIO: 6:1	DIE TYPE: Streamline
DIE FACING: ZrO2	DIE AFTER: -----------------
DIE TEMP: 500	
BILLET TEMP: 2200F	BILLET HEATING: Harrop
BILLET HEAT TIME: 3 Hrs.	
BILLET LUBE: 7052	DIE LUBE: Polygraph
BILLET LUBE THICK: .030	CONTAINER LUBE: Fiske 604
BILLET LUBE BY: Brush	
MAX LOAD: 327-88.2 Ksi	RAM SPEED: .74 ips
ACCUMULATOR PSI: 3050	VALVE SETTING: 1
EXTRUSION LENGTH: 39"	EXTRUSION DESC: Good
EXTRUSION DIA: 1.180	EXTRUSION NOSE BURST: 0
FINAL EXTRUSION RATIO: 6.8:1	EXTRUSION SUCKIN: 7"
COMMENTS: Air cooled	

Figure 26: Sample extrusion record

5.2 Extracting Extrusion Load/Stroke Data from Zenith System

The old Lombard extrusion press in Building 51 had been instrumented under a Westinghouse contract to record load/stroke data on a Zenith computer. The load/stroke data from all the extrusions from 1986 to 1992 were stored on 5.25" floppy diskettes. Unfortunately, these datafiles were stored in a format that was extremely difficult to read on any other computer. There was a real possibility that all these datafiles would be worthless when the Zenith computer was retired with the old press.

The software package "GETDATA" was written to extract the load/stroke data from the original diskettes. This package plots the data on the screen and can then print the data out on a printer or store it in a standard, easy to read ASCII file. All of the extrusion load/stroke curves were converted from the Zenith style files to standard ASCII files on floppy disk. These disks are stored in the Processing Lab office.

6. LABORATORY SAFETY AND HAZARDOUS MATERIALS

6.1 Laboratory Safety

Throughout this program, UES placed a high priority on the health and safety of both its employees and other personnel who entered the Processing Lab. A regular series of safety walkthroughs by the UES Program Manager and Technicians kept safety at the forefront of operational planning.

6.2 Hazardous Materials Handling and Disposal

The proper treatment of Hazardous Materials become an increasingly large task during this program for two reasons. First, regulatory and safety requirements have become considerably more stringent in the past few years. Second, the laboratory relocation necessitated disposal of hundreds of containers of chemicals that had accumulated in the laboratory over the past few decades.

UES personnel instituted many new practices and procedures in order to address environmental concerns. One example is the treatment of the water soluble oil from the presses. The extrusion and forge presses in Building 51 were powered by a water based hydraulic drive system; this water was treated with a soluble oil in order to prevent corrosion. Every 3 months this system was partially or fully drained. When the presses were installed 35 years ago, the plumbing was arranged to dump this waste water directly into the storm sewer (i.e., the river). UES halted this practice. This waste water was instead pumped into 55 gallon drums and then hauled away by the Government for proper disposal. Pumping hundreds of gallons into drums was rather time consuming, but was well worth the effort to protect our environment and to reduce the effluent stream from WPAFB.

Hazardous materials in Buildings 32 and 51 were inventoried by UES personnel and turned in to WPAFB Environmental Management for disposal. This turned to out to be such a large task that a computerized database system was set up to inventory the 415 separate containers of hazardous materials. A sample page of output from this database is shown in Figure 27. Each material had to be fully characterized before EM would accept it for disposal. As a result of this work, only a minimum of chemicals and materials were moved into the new lab in Building 655.

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Material Inventory for Experimental Materials Processing Laboratory - Buildings 32 & 51
Information Compiled by Universal Energy Systems

RECORD NUMBER	DESCRIPTION	QUANTITY	STATE	CONTAINER MATERIAL	CONTAINER SIZE	AMOUNT	BLDG	ROOM	LOCATION	DISPOSE OF ?
14	Abietic Acid	1	solid	glass	1 lb	half	32	201	grey cabinet	yes
32	Aluminum Hyeoroxide	1	solid	glass	4 oz	full	32	201	grey cabinet	yes
74	Aluminum Metal	1	solid	plastic	1 lb	full	32	201	grey cabinet	yes
33	Aluminum Nitrate	1	solid	glass	4 oz	full	32	201	grey cabinet	yes
56	Aluminum Oxide	1	solid	glass	64 oz	3/4 full	32	201	grey cabinet	yes
21	Ammonium Bromide	1	solid	glass	1 lb	full	32	201	grey cabinet	yes
15	Ammonium Chloride	2	solid	glass	1/2 lb	half	32	201	grey cabinet	yes
31	Ammonium Molybrate	1	solid	glass	1/4 lb	half	32	201	grey cabinet	yes
38	Ammonium Persulfate	1	solid	glass	1 lb	full	32	201	grey cabinet	yes
19	Antimony T-ioxide	1	solid	glas	1/4 lb	full	32	201	grey cabinet	yes
36	Barium Sufate	1	solid	glass	16 oz	half	32	201	grey cabinet	yes
13	Boric Acid	2	solid	plastic	1 lb	full	32	201	grey cabinet	yes
51	Boron Nitrite	2	solid	glass	4 oz	full/trace	32	201	grey cabinet	yes
22	Cadium Bromide	1	solid	glass	4 oz	full	32	201	grey cabinet	yes
23	Cadium Chloride	1	solid	glass	4 oz	half	32	201	grey cabinet	yes
18	Calcium Hydroxide	1	solid	glass	1 lb	full	32	201	grey cabinet	yes
25	Cerium (ic) Sulfate	1	solid	glass	4 oz	half	32	201	grey cabinet	yes
20	Cerium Nitrate	1	solid	glass	4 oz	half	32	201	grey cabinet	yes
16	Cerium Oxalate	1	solid	glass	4 oz	full	32	201	grey cabinet	yes
6	Chromium	2	solid	glass	1 lb	full	32	201	grey cabinet	yes
34	Chromium Oxide	1	solid	glass	16 oz	half	32	201	grey cabinet	yes
28	Chromium Potassium Sulfate	1	solid	glass	8 oz	full	32	201	grey cabinet	yes
26	Cobalt (ous) Sulfate	1	solid	glass	8 oz	full	32	201	grey cabinet	yes
1	Cobalt Metal	3	solid	glass	1 lb	full	32	201	grey cabinet	yes
53	Copper Sulfate	1	solid	Plastic	1 gal	1/4 full	32	201	grey cabinet	yes
35	Cupric Chloride	1	solid	glass	12 oz	half	32	201	grey cabinet	yes
29	Cupric Oxide	2	solid	glass	4 oz	1/4 full	32	201	grey cabinet	yes

Figure 27: Sample output from hazardous materials database

APPENDICES

These appendices contain listings of the major material processing operations performed in the Experimental Materials Processing Laboratory under the subject program. Included here are five appendices A-E detailing the Extrusion, Forging, Evacuation, Vacuum Arc Melting and Vacuum Induction Melting operations respectively.

APPENDIX A: LIST OF EXTRUSION OPERATIONS

Billets Processed by Extrusion or Compaction

No.	Source	Die Ratio	Ram Speed cm/s (in/s)	Billet Temp C (F)	Composition
10744	GE/Evendale	Blank	n/a	1038 (1900)	Proprietary (Ni-Alloy)
10745	GE/Evendale	Blank	n/a	838 (1540)	Ti-11.7Al-1.6Zr-1.4 Sn-.7Hf-.5Nb-.13Ru-.2Si-.25Ge-.6Er
10746	GE/Evendale	Blank	n/a	1066 (1950)	Proprietary Ni-Alloy
10747	GE/Evendale	Blank	n/a	1066 (1950)	Proprietary (Ni-Alloy)
10748	GE/Evendale	Blank	n/a	1066 (1950)	Proprietary (Ni-Alloy)
10749	GE/Evendale	Blank	n/a	1066 (1950)	Proprietary (Ni-Alloy)
10750	GE/Evendale	Blank	n/a	1066 (1950)	Proprietary (Ni-Alloy)
10751	GE/Evendale	8.9:1	1.98 (.78)	1199 (2190)	Ti-11.7Al-1.6Zr-1.4 Sn-.7Hf-.5Nb-.13Ru-.2Si-.25Ge-.6Er
10752	GE/Evendale	Blank	n/a	1093 (2000)	Proprietary (Ni-Alloy)
10753	GE/Evendale	Blank	n/a	1093 (2000)	Proprietary (Ni-Alloy)
10754	GE/Evendale	Blank	n/a	1093 (2000)	Proprietary (Ni-Alloy)
10755	GE/Evendale	Blank	n/a	1093 (2000)	Proprietary (Ni-Alloy)
10756	GE/Evendale	Blank	n/a	838 (1540)	Ti-11.7Al-1.6Zr-1.4 Sn-.7Hf-.5Nb-.13Ru-.2Si-.25Ge-.25Er
10757	GE/Evendale	Blank	n/a	838 (1540)	Ti-11.7Al-1.6Zr-1.4 Sn-.7Hf-.5Nb-.13Ru-.25Ge-.6Er
10758	GE/Evendale	Blank	n/a	838 (1540)	Ti-11.7Al-1.6Zr-1.4 Sn-.7Hf-.5Nb-.13Ru-.25Ge-.6Er
10759	GE/Evendale	Blank	n/a	1107 (2025)	Proprietary (Ni-Alloy)

Billets Processed by Extrusion or Compaction

No.	Source	Die Ratio	Ram Speed cm/s (in/s)	Billet Temp C (F)	Composition
10760	GE/Evendale	7:1	2.62 (1.03)	1107 (2025)	Proprietary (Ni-Alloy)
10761	GE/Evendale	7:1	2.77 (1.09)	1121 (2050)	Proprietary (Ni-Alloy)
10762	GE/Evendale	7:1	x	1093 (2000)	Proprietary (Ni-Alloy)
10763	GE/Evendale	7:1	x	1093 (2000)	Proprietary (Ni-Alloy)
10764	GE/Evendale	7:1	x	1079 (1975)	Proprietary (Ni-Alloy)
10765	GE/Evendale	7:1	x	1079 (1975)	Proprietary (Ni-Alloy)
10766	GE/Evendale	7:1	2.59 (1.02)	1052 (1925)	Proprietary (Ni-Alloy)
10767	GE/Evendale	7:1	2.62 (1.03)	1066 (1950)	Proprietary (Ni-Alloy)
10768	Martin Marietta	27:1	1.55 (.61)	849 (1560)	Cu-TiB2
10769	Martin Marietta	27:1	2.26 (.89)	849 (1560)	Cu-TiB2
10770	Martin Marietta	27:1	2.74 (1.08)	849 (1560)	Cu-TiB2
10771	Martin Marietta	27:1	2.29 (.9)	849 (1560)	Cu-TiB2
10772	GE/Evendale	9:1	2.01 (.79)	1199 (2190)	Ti-11.7Al-1.6Zr-1.4 Sn-.7Hf-.5Nb-.13Ru-.2Si-.25Ge-.6Er
10773	GE/Evendale	9:1	1.98 (.78)	1199 (2190)	Ti-11.7Al-1.6Zr-1.4 Sn-.7Hf-.5Nb-.13Ru-.2Si-.25Ge-.6Er
10774	GE/Evendale	9:1	1.96 (.77)	1199 (2190)	Ti-11.7Al-1.6Zr-1.4 Sn-.7Hf-.5Nb-.13Ru-.2Si-.25Ge-.6Er
10775	Martin Marietta	14:1	1.88 (.74)	1300 (2372)	Ti-45Al-2Nb-30v/o-NbB2
10776	Martin Marietta	14:1	1.91 (.75)	1300 (2372)	Ti-45Al-2Nb-20v/o NbB2
10777	Martin Marietta	14:1	1.83 (.72)	1300 (2372)	Ti-45Al-1Ta-30v/o-TaB2

Billets Processed by Extrusion or Compaction

No.	Source	Die Ratio	Ram Speed cm/s (in/s)	Billet Temp C (F)	Composition
10778	GE/Evendale	Blank	n/a	1066 (1950)	Proprietary (Ni-Alloy)
10779	GE/Evendale	7:1	2.74 (1.08)	1135 (2075)	Proprietary (Ni-Alloy)
10780	GE/Evendale	7:1	2.64 (1.04)	1079 (1975)	Proprietary (Ni-Alloy)
10781	UES	4.4:1	1.88 (.74)	420 (788)	2024 Al
10782	UES	4.4:1	13.94 (5.49)	420 (788)	2024 Al
10783	UES	4.4:1	14.05 (5.53)	475 (887)	2024 Al
10784	UES	4.4:1	1.68 (.66)	420 (788)	2024 Al
10785	Pratt & Whitney	10:1	1.75 (.69)	1135 (2075)	Ti-34.1Al-8.86Ta (RSR-1457)
10786	Pratt & Whitney	15:1	1.55 (.61)	1135 (2075)	Ti-34.1Al-8.86Ta (RSR-1457)
10787	Pratt & Whitney	15:1	1.68 (.66)	1163 (2125)	Ti-34.1Al-8.86Ta
10788	Pratt & Whitney	10:1	x	1204 (2200)	Ti-34.1Al-8.86Ta (RSR-1457)
10789	Pratt & Whitney	15:1	x	1204 (2200)	Ti-34.1Al-8.86Ta (RSR-1457)
10790	Pratt & Whitney	15:1	1.75 (.69)	1232 (2250)	Ti-34.1Al-8.86Ta
10791	Pratt & Whitney	20:1	1.85 (.73)	1288 (2350)	Ti-34.1Al-8.86Ta (RSR-1457)
10792	Pratt & Whitney	25:1	.18 (.07)	1288 (2350)	Ti-34.1Al-8.86Ta (RSR-1457)
10793	UES	11.65:1	3.1 (1.22)	1649 (3000)	Nb-.08Si
10794	UES	9.6:1	x	1649 (3000)	Nb-5.0Si
10795	UES	5.76:1	3.61 (1.42)	1649 (3000)	Nb-5Si
10796	Westinghouse	3.69:1	8.81 (3.47)	1232 (2250)	Nb-1Zr
10797	Metcut	4:1	1.7 (.67)	1149 (2100)	Ti-47.5Al-1Mo-1Cr-2 Nb
10798	Martin Marietta	15.5:1	1.73 (.68)	1250 (2282)	Ti-Al-TiB2
10799	Martin Marietta	15.5:1	1.73 (.68)	1250 (2282)	TiAl-TiB2

Billets Processed by Extrusion or Compaction

No.	Source	Die Ratio	Ram Speed cm/s (in/s)	Billet Temp C (F)	Composition
10800	Martin Marietta	15.5:1	1.65 (.65)	1250 (2282)	TiAl-TiB2
10801	Martin Marietta	15.5:1	1.57 (.62)	1250 (2282)	TiAl-TiB2
10802	Pratt & Whitney	9:1	2.62 (1.03)	999 (1830)	NiAl (Alloy C)
10803	McDonnell Douglas	14:1	1.85 (.73)	1343 (2450)	Ti-34Al
10804	McDonnell Douglas	14:1	1.85 (.73)	1343 (2450)	Ti-34Al
10805	McDonnell Douglas	14:1	1.85 (.73)	1343 (2450)	Ti-34Al
10806	McDonnell Douglas	14:1	1.88 (.74)	1343 (2450)	Ti-34Al-2Mn
10807	McDonnell Douglas	14:1	1.78 (.7)	1343 (2450)	Ti-34Al-8Nb
10808	McDonnell Douglas	14:1	1.78 (.7)	1343 (2450)	Ti-34Al-8Nb
10809	McDonnell Douglas	14:1	1.8 (.71)	1343 (2450)	Ti-34Al-5Nb-1Ta
10810	McDonnell Douglas	14:1	1.8 (.71)	1343 (2450)	Ti-34Al-2Cr
10811	UES	9.8:1	2.18 (.86)	1649 (3000)	Nb-3.25Si
10812	Westinghouse	3.69:1	4.39 (1.73)	1093 (2000)	Nb-1Zr
10813	Martin Marietta	15:1	1.6 (.63)	1250 (2282)	TiAl-2V-TiB2
10814	Martin Marietta	15:1	1.68 (.66)	1250 (2282)	TiAl-1V-TiB2
10815	Pratt & Whitney	10:1	1.85 (.73)	1343 (2450)	Ti-52Al-3.5Nb
10816	Pratt & Whitney	20:1	1.65 (.65)	1343 (2450)	Ti-52Al-3.5Nb
10817	Pratt & Whitney	30:1	1.63 (.64)	1343 (2450)	Ti-52Al-3.5Nb
10818	Pratt & Whitney	10:1	1.7 (.67)	1343 (2450)	Ti-53Al-2.5Nb-.3Ta (1461-140-270#A)
10819	Pratt & Whitney	10:1	1.8 (.71)	1343 (2450)	Ti-53Al-2.5Nb-.3Ta (1461-140-270#B)
10820	Pratt & Whitney	10:1	1.73 (.68)	1343 (2450)	Ti-53Al-2.5Nb-.3Ta (1461-270-#A)
10821	Pratt & Whitney	10:1	1.7 (.67)	1343 (2450)	Ti-53Al-2.5Nb-.3Ta (1461-270-B)
10822	Pratt & Whitney	10:1	1.7 (.67)	1343 (2450)	Ti-53Al-2.5Nb-.3Ta (1461-80-140-#A)
10823	Pratt & Whitney	10:1	1.78 (.7)	1343 (2450)	Ti-53Al-2.5Nb-.3Ta (1461-80-140B)

Billets Processed by Extrusion or Compaction

No.	Source	Die Ratio	Ram Speed cm/s (in/s)	Billet Temp C (F)	Composition
10824	GE/Evendale	Blank	n/a	1010 (1850)	Ni-Al-Fe-X
10825	GE/Evendale	Blank	n/a	1010 (1850)	Ni-Al-Fe-X
10826	GE/Evendale	Blank	n/a	1010 (1850)	Ni-Al-Fe-X
10827	GE/Evendale	Blank	n/a	1010 (1850)	Ni-Al-Fe-X
10828	GE/Evendale	Blank	n/a	1010 (1850)	Ni-Al-Fe-X
10829	GE/Evendale	Blank	n/a	1010 (1850)	Ni-Al-Fe-X
10830	GE/Evendale	Blank	n/a	1010 (1850)	Ni-Al-Fe-X
10831	GE/Evendale	6.9:1	2.84 (1.12)	1038 (1900)	Ni-Al-Fe-X
10832	GE/Evendale	6.9:1	3 (1.18)	1038 (1900)	Ni-Al-Fe-X
10833	GE/Evendale	6.9:1	2.54 (1)	1038 (1900)	Ni-Al-Fe-X
10834	GE/Evendale	6.9:1	2.77 (1.09)	1038 (1900)	Ni-Al-Fe-X
10835	GE/Evendale	6.9:1	2.74 (1.08)	1038 (1900)	Ni-Al-Fe-X
10836	GE/Evendale	6.9:1	3.02 (1.19)	1038 (1900)	Ni-Al-Fe-X
10837	GE/Evendale	6.9:1	2.84 (1.12)	1038 (1900)	Ni-Al-Fe-X
10838	GE/Evendale	Blank	n/a	840 (1544)	A/o-Ti-11.7Al-1.6Zr-1.4Sn-.7Hf-.5Nb-.13Ru-.25Ge-.6Er
10839	GE/Evendale	Blank	n/a	840 (1544)	A/o-Ti-11.7Al-1.6Zr-1.4Sn-.7Hf-.5Nb-.13Ru-.2Si-.25Ge-.6Er
10840	GE/Evendale	Blank	n/a	840 (1544)	A/o-Ti-11.7Al-1.6Zr-1.4Sn-.7Hf-.5Nb-.13Ru-.2Si-.25Ge-.6Er
10841	GE/Evendale	Blank	n/a	1200 (2192)	A/o-Ti-11.7Al-1.6Zr-1.4Sn-.7Hf-.5Nb-.13Ru-.2Si-.15Ge-.6Er
10842	GE/Evendale	8.75:1	1.96 (.77)	1200 (2192)	A/o-Ti-11.7Al-1.6Zr-1.4Sn-.7Hf-.5Nb-.13Ru-.2Si-.25Ge-.6Er
10843	GE/Evendale	8.75:1	1.85 (.73)	975 (1787)	A/o-Ti-11.7Al-1.6Zr-1.4Sn-.7Hf-.5Nb-.13Ru-.2Si-.25Ge-.6Er

Billets Processed by Extrusion or Compaction

No.	Source	Die Ratio	Ram Speed cm/s (in/s)	Billet Temp C (F)	Composition
10844	GE/Evendale	8.75:1	1.96 (.77)	1200 (2192)	A/o-Ti-11.7Al-1.6Zr -1.4Sn-.7Hf-.5Nb-.1 3Ru-.2Si-.25Ge-.6Er
10845	GE/Evendale	8.75:1	x	975 (1787)	A/o-Ti-11.7Al-1.6Zr -1.4Sn-.7Hf-.5Nb-.1 3Ru-.2Si-.25Ge-.6Er
10846	SPS Technologies	4.2:1	1.35 (.53)	1149 (2100)	Proprietary Co-Ni-Alloy
10847	SPS Technologies	4.2:1	1.27 (.5)	1149 (2100)	Proprietary Co-Ni-Alloy
10848	SPS Technologies	4.2:1	1.42 (.56)	1149 (2100)	Proprietary Co-Ni-Alloy
10849	SPS Technologies	4.2:1	1.4 (.55)	1149 (2100)	Proprietary Co-Ni-Alloy
10850	SPS Technologies	4.2:1	1.5 (.59)	1149 (2100)	Proprietary Co-Ni-Alloy
10851	SPS Technologies	4.2:1	1.5 (.59)	1149 (2100)	Proprietary Co-Ni-Alloy
10852	SPS Technologies	4.2:1	1.4 (.55)	1149 (2100)	Proprietary Co-Ni-Alloy
10853	SPS Technologies	4.2:1	1.47 (.58)	1149 (2100)	Proprietary Co-Ni-Alloy
10854	SPS Technologies	4.2:1	1.37 (.54)	1149 (2100)	Proprietary Co-Ni-Alloy
10855	SPS Technologies	4.2:1	1.37 (.54)	1149 (2100)	Proprietary Co-Ni-Alloy
10856	Martin Marietta	14.7:1	1.91 (.75)	1400 (2552)	TiAl-TiB2
10857	Martin Marietta	14.7:1	x	1400 (2552)	TiAl-TiB2
10858	Martin Marietta	14.7:1	1.91 (.75)	1400 (2552)	TiAl-TiB2
10859	UES	4.3:1	x	1038 (1900)	IN-100 Cast
10860	UES	4.3:1	.79 (.31)	1149 (2100)	IN-100 Cast
10861	Martin Marietta	14.7:1	x	1400 (2552)	TiAl-TiB2
10862	Martin Marietta	14.7:1	x	1400 (2552)	TiAl-TiB2
10863	Martin Marietta	14.7:1	x	1400 (2552)	TiAl-TiB2

Billets Processed by Extrusion or Compaction

No.	Source	Die Ratio	Ram Speed cm/s (in/s)	Billet Temp C (F)	Composition
10864	Martin Marietta	14.7:1	x	1400 (2552)	TiAl-TiB2
10865	GE/Evendale	21.5:1	1.47 (.58)	1066 (1950)	Ti-25Al-10Nb (IR&D)
10866	GE/Evendale	21.5:1	1.37 (.54)	1066 (1950)	Ti-25Al-10Nb (IR&D)
10867	Martin Marietta	14.7:1	.64 (.25)	1400 (2552)	TiAl-TiB2
10868	Martin Marietta	14.5:1	1.85 (.73)	1400 (2552)	TiAl-TiB2
10869	Martin Marietta	14.7:1	1.5 (.59)	1400 (2552)	TiAl-TiB2
10870	GE/Evendale	7.8:1	1.65 (.65)	1066 (1950)	Ti-25Al-10Nb (IR&D)
10871	GE/Evendale	22:1	1.24 (.49)	1066 (1950)	Ti-25Al-10Nb (IR&D)
10872	McDonnell Douglas	14:1	1.68 (.66)	1343 (2450)	Ti-34Al-5Nb-1Ta
10873	McDonnell Douglas	14:1	1.73 (.68)	1343 (2450)	Ti-34Al-5Nb-1Ta
10874	McDonnell Douglas	14:1	1.57 (.62)	1343 (2450)	Ti-39Al
10875	McDonnell Douglas	14:1	1.57 (.62)	1343 (2450)	Ti-39Al
10876	McDonnell Douglas	14:1	1.4 (.55)	1343 (2450)	Ti-35Al
10877	McDonnell Douglas	14:1	1.47 (.58)	1343 (2450)	Ti-34Al
10878	GE/Evendale	20.5:1	1.6 (.63)	1038 (1900)	Ti-25Al-10Nb (IR&D)
10879	GE/Evendale	20.5:1	1.68 (.66)	1038 (1900)	Ti-25Al-10Nb (IR&D)
10880	GE/Evendale	20.5:1	1.65 (.65)	1038 (1900)	Ti-25Al-10Nb (IR&D)
10881	GE/Evendale	20.5:1	1.55 (.61)	1038 (1900)	Ti-25Al-10Nb (IR&D)
10882	GE/Evendale	20.5:1	1.63 (.64)	1038 (1900)	Ti-25Al-10Nb (IR&D)
10883	McDonnell Douglas	14:1	1.78 (.7)	1343 (2450)	Ti-34Al
10884	McDonnell Douglas	14:1	1.88 (.74)	1343 (2450)	Ti-34Al
10885	McDonnell Douglas	14:1	1.85 (.73)	1343 (2450)	Ti-34Al-2Er
10886	McDonnell Douglas	14:1	1.88 (.74)	1343 (2450)	Ti-34Al-2Er
10887	McDonnell Douglas	14:1	1.78 (.7)	1343 (2450)	Ti-38Al
10888	McDonnell Douglas	14:1	1.78 (.7)	1343 (2450)	Ti-38Al
10889	McDonnell Douglas	14:1	1.88 (.74)	1343 (2450)	Ti-34Al-5Nb-1Ta

Billets Processed by Extrusion or Compaction

No.	Source	Die Ratio	Ram Speed cm/s (in/s)	Billet Temp C (F)	Composition
10890	GE/Evendale	8:1	1.37 (.54)	841 (1545)	Ti-9.2Al-5.1Hf-17.2 Ta-.01B
10891	GE/Evendale	8:1	x	841 (1545)	Ti-9.2Al-5.1Hf-17.2 Ta-.01B
10892	GE/Evendale	8:1	2.36 (.93)	841 (1545)	Ti-9.2Al-5.1Hf-17.2 Ta-.01B
10893	GE/Evendale	Zr02	1.45 (.57)	841 (1545)	Ti-9.2Al-5.1Hf-17.2 Ta-.01B
10894	GE/Evendale	8:1	1.47 (.58)	841 (1545)	Ti-9.2Al-5.1Hf-17.2 Ta-.01B
10895	GE/Evendale	8:1	1.5 (.59)	841 (1545)	Ti-9.2Al-5.1Hf-17.2 Ta-.01B
10896	GE/Evendale	26:1	1.52 (.6)	1010 (1850)	Ti-25Al-10Nb
10897	GE/Evendale	26:1	1.6 (.63)	1010 (1850)	Ti-25Al-10Nb
10898	GE/Evendale	26:1	1.6 (.63)	1010 (1850)	Ti-25Al-10Nb
10899	GE/Evendale	27:1	1.75 (.69)	1010 (1850)	Ti-25Al-10Nb
10900	GE/Evendale	27:1	x	1010 (1850)	Ti-25Al-10Nb
10901	GE/Evendale	27:1	No data	1010 (1850)	Ti-25Al-10Nb
10902	GE/Evendale	27:1	No data	1010 (1850)	Ti-25Al-10Nb
10903	GE/Evendale	27:1	No data	1010 (1850)	Ti-25Al-10Nb
10904	GE/Evendale	8:1	1.57 (.62)	902 (1655)	Ti-11.7Al-5.2Hf-17. 5Ta-.01B
10905	GE/Evendale	8:1	1.45 (.57)	902 (1655)	Ti-11.7Al-5.2Hf-17. 5Ta-.01B
10906	GE/Evendale	8:1	1.57 (.62)	902 (1655)	Ti-11.7Al-5.2Hf-17. 5Ta-.01B
10907	GE/Evendale	8:1	1.65 (.65)	902 (1655)	Ti-11.7Al-5.2Hf-17. 5Ta-.01B
10908	GE/Evendale	8:1	1.65 (.65)	902 (1655)	Ti-11.7Al-5.2Hf-17. 5Ta-.01B
10909	GE/Evendale	8:1	1.63 (.64)	902 (1655)	Ti-11.7Al-5.2Hf-17. 5Ta-.01B

Billets Processed by Extrusion or Compaction

No.	Source	Die Ratio	Ram Speed cm/s (in/s)	Billet Temp C (F)	Composition
10910	GE/Evendale	8:1	1.68 (.66)	902 (1655)	Ti-11.7Al-5.2Hr-17.5Ta-.01B
10911	GE/Evendale	8:1	x	975 (1787)	Ti-22Al-27Nb
10912	GE/Evendale	8:1	1.63 (.64)	975 (1787)	Ti-22Al-27Nb
10913	GE/Evendale	8:1	1.6 (.63)	975 (1787)	Ti-22Al-27Nb
10914	GE/Evendale	8:1	1.68 (.66)	975 (1787)	Ti-22Al-27Nb
10915	GE/Evendale	8:1	1.65 (.65)	975 (1787)	Ti-22Al-27Nb
10916	GE/Evendale	8:1	1.65 (.65)	975 (1787)	Ti-22Al-27Nb
10917	WRDC/MLLM	10.7:1	1.4 (.55)	1079 (1975)	Ti-48Al-2.5Nb-.3Ta & Ti-30Nb
10918	WRDC/MLLM	5.6:1	1.85 (.73)	1079 (1975)	Ti-48Al-2.5Nb-.3Ta & Ti-30Nb
10919	GE/Evendale	8:1	1.93 (.76)	1100 (2012)	Ti-13.2Al-4.8Sn-18.9Nb-1.1Ce
10920	GE/Evendale	8:1	1.93 (.76)	1100 (2012)	Ti-13.2Al-4.8Sn-18.9Nb-1.1Ce
10921	GE/Evendale	8:1	1.93 (.76)	1100 (2012)	Ti-13.2Al-4.8Sn-18.9Nb-1.1Ce
10922	GE/Evendale	8:1	1.96 (.77)	1100 (2012)	Ti-13.2Al-4.8Sn-18.9Nb-1.1Ce
10923	GE/Evendale	8:1	1.96 (.77)	1100 (2012)	Ti-13.2Al-4.8Sn-18.9Nb-1.1Ce
10924	GE/Evendale	8:1	1.96 (.77)	1100 (2012)	Ti-13.2Al-4.8SZn-18.9Nb-1.1Ce
10925	GE/Evendale	8:1	1.96 (.77)	1100 (2012)	Ti-13.2Al-4.8SZn-18.9Nb-1.1Ce
10926	UES	12:1	2.44 (.96)	1482 (2700)	Nb-.08Si
10927	GE/Evendale	8:1	1.88 (.74)	1316 (2400)	Ti-31.6Al-16.9Ta
10928	GE/Evendale	8:1	1.91 (.75)	1316 (2400)	Ti-31.6Al-16.9Ta
10929	GE/Evendale	8:1	1.68 (.66)	1316 (2400)	Ti-31.6Al-16.9Ta
10930	GE/Evendale	8:1	1.91 (.75)	1316 (2400)	Ti-31.6Al-16.9Ta
10931	GE/Evendale	8:1	1.93 (.76)	1316 (2400)	Ti-31.6Al-16.9Ta

Billets Processed by Extrusion or Compaction

No.	Source	Die Ratio	Ram Speed cm/s (in/s)	Billet Temp C (F)	Composition
10932	GE/Evendale	8.5:1	1.96 (.77)	1316 (2400)	Ti-31.6Al-16.9Ta
10933	GE/Evendale	8:1	1.91 (.75)	1316 (2400)	Ti-31.6Al-16.9Ta
10934	UES	12:1	3 (1.18)	1482 (2700)	Nb-.03Si
10935	GE/Evendale	8.4:1	1.93 (.76)	1316 (2400)	Ti-33.3Al-1.8Mn-4.8 Nb
10936	GE/Evendale	8.4:1	1.91 (.75)	1316 (2400)	Ti-33.3Al-2.8Mn-4.8 Nb
10937	GE/Evendale	8.4:1	1.88 (.74)	1316 (2400)	Ti-33.3Al-2.8Mn-4.8 Nb
10938	GE/Evendale	8.4:1	1.93 (.76)	1316 (2400)	Ti-33.3Al-2.8Mn-4.8 Nb
10939	GE/Evendale	8.4:1	1.91 (.75)	1316 (2400)	Ti-33.3Al-2.8Mn-4.8 Nb
10940	GE/Evendale	8.4:1	1.93 (.76)	1316 (2400)	Ti-33.3Al-2.8Mn-4.8 Nb
10941	GE/Evendale	8.4:1	1.88 (.74)	1316 (2400)	Ti-33.3Al-2.8Mn-4.8 Nb
10942	GE/Evendale	7.5:1	1.45 (.57)	841 (1545)	Ti-9.2Al-5.1Hf-17.2 Ta-.01B
10943	GE/Evendale	20:1	1.88 (.74)	1371 (2500)	Ti-Al Gamma (GE IR&D)
10944	GE/Evendale	20:1	1.83 (.72)	1371 (2500)	Ti-Al Gamma (GE IR&D)
10945	GE/Evendale	9.5:1	1.8 (.71)	1371 (2500)	Ti-Al Gamma (GE IR&D)
10946	GE/Evendale	9.5:1	x	1371 (2500)	Ti-Al Gamma (GE IR&D)
10947	GE/Evendale	20:1	1.8 (.71)	1371 (2500)	Ti-Al Gamma (GE IR&D)
10948	GE/Evendale	7.5:1	1.5 (.59)	841 (1545)	Ti-9.2Al-5.1Hf-17.2 Ta-.01B
10949	GE/Evendale	20:1	1.8 (.71)	1316 (2400)	Ti-Al Gamma (GE IR&D)
10950	GE/Evendale	9.5:1	x	1316 (2400)	Ti-Al Gamma (GE IR&D)

Billets Processed by Extrusion or Compaction

No.	Source	Die Ratio	Ram Speed cm/s (in/s)	Billet Temp C (F)	Composition
10951	Westinghouse	3.7:1	7.87 (3.1)	1093 (2000)	Nb-1Zr
10952	Westinghouse	4.2:1	3.43 (1.35)	1000 (1832)	W-LPS
10953	Westinghouse	4.2:1	2.49 (.98)	1000 (1832)	W-LPS
10954	WRDC/MLLM	10.7:1	1.7 (.67)	1079 (1975)	Ti-48Al-2.5Nb-.3Ta & Ti-30Nb
10955	WRDC/MLLM	10.7:1	1.5 (.59)	1079 (1975)	Ti-48Al-2.5Nb-.3Ta & Ti-30Nb
10956	Westinghouse	5:1	2.13 (.84)	1000 (1832)	W-LPS
10957	Westinghouse	5:1	2.06 (.81)	1000 (1832)	W-LPS
10958	Metcut	Blank	n/a	1093 (2000)	Ti-Al (Gamma)
10959	Metcut	Blank	n/a	1093 (2000)	Ti-Al (Gamma)
10960	Westinghouse	6.2:1	1.91 (.75)	1000 (1832)	W-LPS
10961	Westinghouse	6.2:1	1.8 (.71)	1000 (1832)	W-LPS
10962	GE/Evendale	9.5:1	1.98 (.78)	1316 (2400)	Ti-Al Gamma (IR&D)
10963	GE/Evendale	9.5:1	1.88 (.74)	1316 (2400)	Ti-Al Gamma (IR&D)
10964	GE/Evendale	9.5:1	1.88 (.74)	1316 (2400)	Ti-Al Gamma (IR&D)
10965	GE/Evendale	9.5:1	1.88 (.74)	1316 (2400)	Ti-Al Gamma (IR&D)
10966	GE/Evendale	9.5:1	1.8 (.71)	1316 (2400)	Ti-Al Gamma (IR&D)
10967	GE/Evendale	20:1	1.78 (.7)	1316 (2400)	Ti-Al Gamma (IR&D)
10968	GE/Evendale	9.5:1	1.83 (.72)	1316 (2400)	Ti-Al Gamma (IR&D)
10969	GE/Evendale	9.5:1	1.63 (.64)	1316 (2400)	Ti-Al Gamma (IR&D)
10970	GE/Evendale	9.5:1	1.91 (.75)	1316 (2400)	Ti-Al Gamma (IR&D)
10971	GE/Evendale	20:1	x	1316 (2400)	Ti-Al Gamma (IR&D)
10972	Metcut	10.7:1	x	1177 (2150)	Ti-Al Gamma
10973	WRDC/MLLM	--	1.83 (.72)	1204 (2200)	IN-100
10974	Metcut	5.9:1	1.5 (.59)	1093 (2000)	Ti-Al Gamma
10975	GE/Evendale	Blank	n/a	838 (1540)	Ti-1300
10976	GE/Evendale	Blank	n/a	838 (1540)	Ti-1300

Billets Processed by Extrusion or Compaction

No.	Source	Die Ratio	Ram Speed cm/s (in/s)	Billet Temp C (F)	Composition
10977	GE/Evendale	9.2:1	1.93 (.76)	1371 (2500)	Ti-Al Gamma (IR&D)
10978	GE/Evendale	9.2:1	1.88 (.74)	1371 (2500)	Ti-Al Gamma (IR&D)
10979	GE/Evendale	9.2:1	1.91 (.75)	1371 (2500)	Ti-Gamma (IR&D)
10980	GE/Evendale	9.5:1	x	1371 (2500)	Ti-Al Gamma (IR&D)
10981	GE/Evendale	9.5:1	1.85 (.73)	1371 (2500)	Ti-Al Gamma (IR&D)
10982	GE/Evendale	9.5:1	1.8 (.71)	1371 (2500)	Ti-Al Gamma (IR&D)
10983	GE/Evendale	9.5:1	1.7 (.67)	1371 (2500)	Ti-Al Gamma (IR&D)
10984	GE/Evendale	9.5:1	x	1371 (2500)	Ti-Al-Gamma (IR&D)
10985	GE/Evendale	9.2:1	1.78 (.7)	1371 (2500)	Ti-Al Gamma (IR&D)
10986	GE/Evendale	20:1	1.5 (.59)	1371 (2500)	Ti-Al Gamma (IR&D)
10987	GE/Evendale	20:1	1.55 (.61)	1371 (2500)	Ti-Al Gamma (IR&D)
10988	GE/Evendale	20:1	1.65 (.65)	1371 (2500)	Ti-Al Gamma (IR&D)
10989	GE/Evendale	Blank	n/a	838 (1540)	Ti-1300
10990	GE/Evendale	Blank	n/a	838 (1540)	Ti-1300
10991	GE/Evendale	Blank	n/a	838 (1540)	Ti-1300
10992	GE/Evendale	Blank	n/a	838 (1540)	Ti-1300
10993	GE/Evendale	Blank	n/a	838 (1540)	Ti-1300
10994	GE/Evendale	8.9:1	1.98 (.78)	1199 (2190)	Ti-1300
10995	GE/Evendale	8.9:1	1.93 (.76)	1199 (2190)	Ti-1300
10996	GE/Evendale	8.9:1	1.91 (.75)	1199 (2190)	Ti-1300
10997	GE/Evendale	8.9:1	1.93 (.76)	1199 (2190)	Ti-1300
10998	GE/Evendale	8.9:1	2.54 (1)	1199 (2190)	Ti-1300
10999	GE/Evendale	8.9:1	1.96 (.77)	1199 (2190)	Ti-1300
11000	GE/Evendale	8.9:1	1.93 (.76)	1199 (2190)	Ti-1300
11001	McDonnell Douglas	14:1	1.85 (.73)	1066 (1950)	Ti-5.5Al-.5B-1
11002	McDonnell Douglas	14:1	1.93 (.76)	1066 (1950)	Ti-5.5Al-.5B-2
11003	McDonnell Douglas	14:1	1.93 (.76)	1066 (1950)	Ti-5.5Al-4V-.5B-1

Billets Processed by Extrusion or Compaction

No.	Source	Die Ratio	Ram Speed cm/s (in/s)	Billet Temp C (F)	Composition
11004	McDonnell Douglas	14:1	1.96 (.77)	1066 (1950)	Ti-5.5Al-4V-.5B-2
11005	McDonnell Douglas	14:1	1.96 (.77)	1066 (1950)	Ti-5.5Al-1B-1
11006	McDonnell Douglas	14:1	x	1066 (1950)	Ti-5.5Al-1B-2
11007	McDonnell Douglas	14:1	1.98 (.78)	1066 (1950)	Ti-7Al-4V-.5B-1
11008	McDonnell Douglas	14:1	2.01 (.79)	1066 (1950)	Ti-7Al-4V-.5B-2
11009	McDonnell Douglas	14:1	1.93 (.76)	1066 (1950)	Ti-7Al-1B-1
11010	McDonnell Douglas	14:1	2.01 (.79)	1066 (1950)	Ti-7Al-1B-2
11011	WRDC/MLLM	4:1	1.75 (.69)	1149 (2100)	IN-100
11012	UES	11.8:1	1.3 (.51)	1482 (2700)	Nb-.38Si
11013	McDonnell Douglas	14:1	1.93 (.76)	1343 (2450)	Ti-34Al-5Nb-1Ta-2
11014	McDonnell Douglas	14:1	1.88 (.74)	1343 (2450)	Ti-34Al-2Cr
11015	Pratt & Whitney	Blank	n/a	1066 (1950)	Ti-34Al-9Ta
11016	Pratt & Whitney	Blank	n/a	1066 (1950)	Ti-34Al-9Ta
11017	Pratt & Whitney	Blank	n/a	1066 (1950)	Ti-34Al-9Ta
11018	Pratt & Whitney	10:1	1.3 (.51)	1066 (1950)	Ti-34Al-9Ta
11019	GE/Evendale	23:1	1.55 (.61)	1010 (1850)	Ti-24.5Al-6Nb-2Ta-2 Mo-2V
11020	GE/Evendale	23:1	1.24 (.49)	1010 (1850)	Ti-24.5Al-6Nb-2Ta-2 Mo-2V
11021	Metcut	10.2:1	1.88 (.74)	1288 (2350)	Ti-Al Gamma
11022	UES	4.3:1	2.24 (.88)	1427 (2600)	Nb-3.5Si
11023	Pratt & Whitney	10:1	1.63 (.64)	1066 (1950)	Ti-34Al-9Ta
11024	Pratt & Whitney	10:1	2.46 (.97)	1066 (1950)	Ti-34Al-9Ta
11025	Pratt & Whitney	10:1	1.96 (.77)	1066 (1950)	Ti-34Al-9Ta
11026	Metcut	6:1	1.52 (.6)	1054 (1930)	Ti-Al
11027	Garrett Corp	8:1	1.57 (.62)	1049 (1920)	Ti-25Al-10Nb-3V-1Mo
11028	Metcut	6:1	1.83 (.72)	1288 (2350)	Ti-Al
11029	Metcut	6:1	1.6 (.63)	1288 (2350)	Ti-Al

Billets Processed by Extrusion or Compaction

No.	Source	Die Ratio	Ram Speed cm/s (in/s)	Billet Temp C (F)	Composition
11030	Westinghouse	4.3:1	2.59 (1.02)	1000 (1832)	W-LPS
11031	Westinghouse	5.2:1	1.75 (.69)	1000 (1832)	W-LPS
11032	Case Western	12.8:1	2.74 (1.08)	1100 (2012)	Ni-Al
11033	Garrett Corp	8:1	1.83 (.72)	1066 (1950)	Ti-25Al-10Nb-3V-1Mo
11034	Case Western	12.8:1	2.67 (1.05)	1100 (2012)	Ni-Al
11035	Case Western	12.8:1	2.84 (1.12)	1100 (2012)	Ni-Al
11036	Case Western	12.8:1	2.74 (1.08)	1100 (2012)	Ni-Al
11037	Case Western	12.8:1	2.79 (1.1)	1100 (2012)	Ni-Al
11038	Case Western	12.8:1	2.62 (1.03)	1100 (2012)	Ni-Al
11039	Case Western	12.8:1	2.72 (1.07)	1100 (2012)	Ni-Al
11040	Case Western	12.8:1	2.34 (.92)	1100 (2012)	Ni-Al
11041	Case Western	12.8:1	2.84 (1.12)	800 (1472)	Ni-Al
11042	Case Western	12.8:1	2.57 (1.01)	800 (1472)	Ni-Al
11043	Case Western	12.8:1	2.64 (1.04)	800 (1472)	Ni-Al
11044	Case Western	12.8:1	2.39 (.94)	800 (1472)	Ni-Al
11045	Case Western	12.8:1	2.62 (1.03)	800 (1472)	Ni-Al
11046	Case Western	12.8:1	2.67 (1.05)	800 (1472)	Ni-Al
11047	Case Western	12.8:1	2.51 (.99)	800 (1472)	Ni-Al
11048	Case Western	12.8:1	2.62 (1.03)	800 (1472)	Ni-Al
11049	UES	6:1	1.68 (.66)	1204 (2200)	IN-100
11050	UES	13:1	x	1482 (2700)	Nb-Si
11051	Garrett Corp	8:1	1.88 (.74)	1049 (1920)	Ti-25Al-10Nb-3V-1Mo
11052	Garrett Corp	8:1	1.8 (.71)	1049 (1920)	Ti-25Al-10Nb-3V-1Mo
11053	Garrett Corp	8:1	1.78 (.7)	1049 (1920)	Ti-25Al-10Nb-3V-1Mo
11054	Garrett Corp	8:1	x	1049 (1920)	Ti-25Al-10Nb-3V-1Mo
11055	Garrett Corp	8:1	1.88 (.74)	1049 (1920)	Ti-25Al-10Nb-3V-1Mo
11056	Garrett Corp	8:1	1.85 (.73)	1049 (1920)	Ti-25Al-10Nb-3V-1Mo

Billets Processed by Extrusion or Compaction

No.	Source	Die Ratio	Ram Speed cm/s (in/s)	Billet Temp C (F)	Composition
11057	Garrett Corp	8:1	1.78 (.7)	1049 (1920)	Ti-25Al-10Nb-3V-1Mo
11058	Garrett Corp	8:1	1.83 (.72)	1049 (1920)	Ti-25Al-10Nb-3V-1Mo
11059	Garrett Corp	8:1	1.8 (.71)	1049 (1920)	Ti-25Al-10Nb-3V-1Mo
11060	Garrett Corp	8:1	1.91 (.75)	1049 (1920)	Ti-25Al-10Nb-3V-1Mo
11061	Garrett Corp	8:1	1.91 (.75)	1049 (1920)	Ti-25Al-10Nb-3V-1Mo
11062	UES	11.8:1	1.55 (.61)	1482 (2700)	Nb-38Si
11063	Pratt & Whitney	9:1	2.74 (1.08)	1093 (2000)	Ni-Al
11064	UES	3.8:1	2.59 (1.02)	1649 (3000)	Nb-Si
11065	UES	5.7:1	2.67 (1.05)	1649 (3000)	Nb-Nb5Si3
11066	Metcut	Blank	n/a	1093 (2000)	Ti-3Al
11067	Case Western	6:1	3.1 (1.22)	1100 (2012)	Ni-Al
11068	Case Western	6:1	3.05 (1.2)	1100 (2012)	Ni-Al
11069	Case Western	6:1	3.1 (1.22)	1100 (2012)	Ni-Al
11070	Case Western	6:1	3.15 (1.24)	1100 (2012)	Ni-Al
11071	Case Western	6:1	3.18 (1.25)	1100 (2012)	Ni-Al
11072	Case Western	6:1	3.07 (1.21)	1100 (2012)	Ni-Al
11073	McDonnell Douglas	10:1	1.78 (.7)	1343 (2450)	Ti-39Al
11074	McDonnell Douglas	10:1	0.61 ips	1343 (2450)	Ti-39Al
11075	McDonnell Douglas	10:1	1.73 (.68)	1343 (2450)	Ti-39Al
11076	Metcut	6:1	1.68 (.66)	1232 (2250)	Ti3Al
11077	McDonnell Douglas	14:1	1.75 (.69)	1343 (2450)	Ti-34Al
11078	McDonnell Douglas	14:1	1.7 (.67)	1343 (2450)	Ti-34Al
11079	McDonnell Douglas	14:1	1.88 (.74)	1260 (2300)	Ti-16Al-2Er
11080	McDonnell Douglas	14:1	1.85 (.73)	1260 (2300)	Ti-16Al-2Er
11081	UES	6:1	1.17 (.46)	1177 (2150)	Ti-48Al
11082	UES	6:1	1.47 (.58)	1232 (2250)	Ti-48Al
11083	UES	6:1	1.68 (.66)	1204 (2200)	IN-100

Billets Processed by Extrusion or Compaction

No.	Source	Die Ratio	Ram Speed cm/s (in/s)	Billet Temp C (F)	Composition
11084	WRDC/MLLS	12:1	1.68 (.66)	1343 (2450)	Ti-Al Gamma
11085	WRDC/MLLS	12:1	1.42 (.56)	1343 (2450)	Ti-Al Gamma
11086	WRDC/MLLS	12:1	1.65 (.65)	1343 (2450)	TiAl Gamma
11087	WRDC/MLLS	10:1	1.73 (.68)	1343 (2450)	TiAl Gamma
11088	UES	12:1	2.11 (.83)	1482 (2700)	Nb-Si
11089	Martin Marietta	14:1	1.4 (.55)	1399 (2550)	Nb-48Al-26Ti at%
11090	Martin Marietta	13.3:1	1.91 (.75)	1399 (2550)	Nb-45Al-26Ti-5NbTiB 2 at%
11091	Martin Marietta	13.8:1	1.83 (.72)	1399 (2550)	Nb-48Al-26Ti-10NbTi 2 at%
11092	Martin Marietta	13.8:1	1.88 (.74)	1399 (2550)	Nb-48Al-26Ti-10NbTi 2 at%
11093	McDonnell Douglas	14:1	1.75 (.69)	1288 (2350)	Ti-34Al
11094	McDonnell Douglas	14:1	1.65 (.65)	1288 (2350)	Ti-34Al-1Si
11095	McDonnell Douglas	14:1	1.75 (.69)	1288 (2350)	Ti-34Al-1W
11096	McDonnell Douglas	14:1	1.7 (.67)	1288 (2350)	Ti-34Al-1Si
11097	McDonnell Douglas	14:1	1.78 (.7)	1288 (2350)	Ti-34Al-.1C
11098	McDonnell Douglas	16:1	.81 (.32)	454 (850)	Al-9Ti-.3Er
11099	Westinghouse	4:1	2.36 (.93)	1000 (1832)	W-LPS
11100	Westinghouse	4:1	2.79 (1.1)	1000 (1832)	W-LPS
11101	UES	7.13:1	1.73 (.68)	1204 (2200)	IN-100
11102	Martin Mariotta	13.5:1	1.83 (.72)	1399 (2550)	Ti-48Al-26Nb-At%
11103	UES	2.7:1	1.17 (.46)	1649 (3000)	Nb-6.62Si
11104	McDonnell Douglas	13.5:1	1.85 (.73)	1343 (2450)	Ti-34Al-.1Si
11105	McDonnell Douglas	13.5:1	1.83 (.72)	1343 (2450)	Ti-34Al-.05Si
11106	McDonnell Douglas	13.5:1	1.91 (.75)	1343 (2450)	Ti-34Al
11107	McDonnell Douglas	13.5:1	1.88 (.74)	1288 (2350)	Ti-34Al-.1Si
11108	Case Western	6:1	3 (1.18)	900 (1652)	Ni-Al

Billets Processed by Extrusion or Compaction

No.	Source	Die Ratio	Ram Speed cm/s (in/s)	Billet Temp C (F)	Composition
11109	Case Western	6:1	3.02 (1.19)	900 (1652)	Ni-Al
11110	Case Western	6:1	3.25 (1.28)	900 (1652)	Ni-Al
11111	Case Western	6:1	3.3 (1.3)	900 (1652)	Ni-Al
11112	Case Western	6:1	3.25 (1.28)	900 (1652)	Ni-Al
11113	Case Western	6:1	3.3 (1.3)	900 (1652)	Ni-Al
11114	GE/Evendale	26.5:1	1.47 (.58)	982 (1800)	Alpha-2 Ti (IR&D)
11115	GE/Evendale	26.5:1	1.55 (.61)	982 (1800)	Alpha-2 Ti (IR&D)
11116	GE/Evendale	26.5:1	1.35 (.53)	982 (1800)	Alpha-2 Ti (IR&D)
11117	GE/Evendale	26.5:1	1.73 (.68)	982 (1800)	Alpha-2 Ti (IR&D)
11118	GE/Evendale	26.5:1	1.63 (.64)	982 (1800)	Alpha-2 Ti (IR&D)
11119	GE/Evendale	26.5:1	1.68 (.66)	982 (1800)	Alpha-2 Ti (IR&D)
11120	Metcut	6:1	x	1177 (2150)	Ti-Al Gamma
11121	UES	6:1	1.88 (.74)	1204 (2200)	IN-100
11122	Metcut	6.03:1	2.01 (.79)	1371 (2500)	Ti-Al Gamma
11123	Westinghouse	6:1	2.21 (.87)	1000 (1832)	W-Powder
11124	Metcut	4.3:1	1.96 (.77)	1177 (2150)	Ti-Al Gamma
11125	Martin Marietta	16:1	2.34 (.92)	1000 (1832)	IR&D
11126	Martin Marietta	16:1	2.41 (.95)	1000 (1832)	IR&D
11127	Martin Marietta	16:1	2.34 (.92)	1000 (1832)	IR&D
11128	Westinghouse	6:1	1.96 (.77)	1000 (1832)	W-Powder
11129	Westinghouse	6:1	1.47 (.58)	1000 (1832)	W-Powder
11130	Westinghouse	6:1	x	1000 (1832)	W-Powder
11131	UES	6:1	2.26 (.89)	1204 (2200)	IN-100
11132	UES	7.5:1	2.54 (1)	1482 (2700)	Nb-.08Si
11133	WRDC/MLLM	6:1	.86 (.34)	149 (300)	2024 Al
11134	WRDC/MLLM	6:1	x	371 (700)	2024 Al
11135	WRDC/MLLM	6:1	.46 (.18)	149 (300)	2024 Al

Billets Processed by Extrusion or Compaction

No.	Source	Die Ratio	Ram Speed cm/s (in/s)	Billet Temp C (F)	Composition
11136	WRDC/MLLM	6:1	.53 (.21)	371 (700)	2024 Al
11137	WRDC/MLLM	17:1	.46 (.18)	149 (300)	2024 Al
11138	WRDC/MLLM	17:1	.53 (.21)	371 (700)	2024 Al
11139	WRDC/MLLM	17:1	x	149 (300)	2024 Al
11140	WRDC/MLLM	17:1	.56 (.22)	371 (700)	2024 Al
11141	WRDC/MLLM	6:1	4.47 (1.76)	149 (300)	2024 Al
11142	WRDC/MLLM	6:1	6.43 (2.53)	371 (700)	2024 Al
11143	WRDC/MLLM	17:1	3.35 (1.32)	149 (300)	2024 Al
11144	WRDC/MLLM	17:1	5.82 (2.29)	371 (700)	2024 Al
11145	WRDC/MLLM	6:1	.56 (.22)	371 (700)	2024 Al
11146	WRDC/MLLM	6:1	.56 (.22)	149 (300)	2024 Al
11147	UES	4.2:1	1.8 (.71)	1038 (1900)	Ti-6Al-2Sn-4Zr-2Mo
11148	UES	4.2:1	1.8 (.71)	993 (1820)	Ti-6Al-2Sn-4Zr-2Mo
11149	UES	4.03:1	1.8 (.71)	954 (1750)	Ti-6Al-2Sn-4Zr-2Mo
11150	UES	3.99:1	1.63 (.64)	916 (1680)	Ti-6Al-2Sn-4Zr-2Mo
11151	Westinghouse	6.5:1	1.93 (.76)	1000 (1832)	W-LPS
11152	Westinghouse	6.5:1	1.6 (.63)	1000 (1832)	W-LPS
11153	Westinghouse	6.5:1	1.98 (.78)	1000 (1832)	W-LPS
11154	Westinghouse	6.5:1	2.24 (.88)	1000 (1832)	W-LPS
11155	Illinois Institute	16.3:1	8.86 (3.49)	1127 (2060)	Ni-70.6Al-26.4Ti
11156	Illinois Institute	16.3:1	8.97 (3.53)	1127 (2060)	Ni-59.7Al-25.6Mo-20 .7Ti
11157	GE/Evendale	20.5:1	2.24 (.88)	1371 (2500)	Ti-Al Gamma
11158	GE/Evendale	20.5:1	No data	1371 (2500)	Ti-Al Gamma
11159	GE/Evendale	20.5:1	1.63 (.64)	1371 (2500)	TiAl Gamma
11160	GE/Evendale	27:1	2.16 (.85)	954 (1750)	TiAl Alpha II
11161	GE/Evendale	27:1	No data	954 (1750)	TiAl Alpha II

Billets Processed by Extrusion or Compaction

No.	Source	Die Ratio	Ram Speed cm/s (in/s)	Billet Temp C (F)	Composition
11162	Westinghouse	6:1	1.7 (.67)	1000 (1832)	W-LPS
11163	Metcut	6.9:1	1.96 (.77)	1288 (2350)	Ti-Al (Gamma G-35)
11164	UES	2.5:1	2.92 (1.15)	1760 (3200)	Nb-Si (Re-extrude #11103)
11165	UD	6.5:1	1.63 (.64)	1222 (2232)	Ti-Al Gamma
11166	WL/MLLM	6.5:1	1.6 (.63)	1222 (2232)	Ti-Al Gamma
11167	Metcut	6.5:1	1.98 (.78)	1327 (2420)	TiAl Gamma
11168	Metcut	6.5:1	2.01 (.79)	1327 (2420)	TiAl Gamma
11169	Metcut	6.5:1	2.03 (.8)	1327 (2420)	TiAl Gamma
11170	UES	10.9:1	3.84 (1.51)	1010 (1850)	Ti-6-6-2
11171	UES	10.9:1	4.42 (1.74)	1010 (1850)	Ti-6-6-2
11172	UES	10.9:1	4.47 (1.76)	1010 (1850)	Ti-6-6-2
11173	UES	4:1	4.39 (1.73)	260 (500)	Ti-6-2-4-2
11174	UES	4:1	.71 (.28)	916 (1680)	Ti-6-2-4-2
11175	UES	3.94:1	4.5 (1.77)	993 (1820)	Ti-6-2-4-2
11176	UES	3.92:1	.61 (.24)	993 (1820)	Ti-6-2-4-2
11177	UES	4:1	2.03 (.8)	1200 (2192)	Al-25Ti-8Cr
11178	WL/MLLM	Blank	n/a	450 (842)	Al-Cu
11179	WL/MLLM	Blank	n/a	450 (842)	Al-Cu
11180	WL/MLLM	Blank	n/a	450 (842)	Al-Cu
11181	WL/MLLM	Blank	n/a	450 (842)	Al-Cu
11182	WL/MLLM	Blank	n/a	450 (842)	Al-Cu
11183	WL/MLLM	10:1	No data	616 (1140)	Al-Cu
11184	WL/MLLM	10:1	.66 (.26)	560 (1040)	Al-Cu
11185	WL/MLLM	10:1	.61 (.24)	560 (1040)	Al-Cu
11186	WL/MLLM	10:1	.66 (.26)	560 (1040)	Al-Cu
11187	WL/MLLM	10:1	.61 (.24)	560 (1040)	Al-Cu

Billets Processed by Extrusion or Compaction

No.	Source	Die Ratio	Ram Speed cm/s (in/s)	Billet Temp C (F)	Composition
11188	Martin Marietta	16.5:1	1.27 (.5)	1000 (1832)	Fe-Al
11189	Martin Marietta	16.5:1	x	1000 (1832)	Fe-Al
11190	McDonnell Douglas	13.7:1	1.88 (.74)	1343 (2450)	Ti-34Al
11191	McDonnell Douglas	13.7:1	1.93 (.76)	1343 (2450)	Ti-Al
11192	McDonnell Douglas	13.7:1	1.85 (.73)	1343 (2450)	Ti-Al
11193	McDonnell Douglas	13.7:1	1.88 (.74)	1343 (2450)	Ti-Al
11194	McDonnell Douglas	13.7:1	1.98 (.78)	1343 (2450)	Ti-Al
11195	McDonnell Douglas	13.7:1	2.03 (.8)	1343 (2450)	Ti-Al
11196	WRDC/MLLM	Blank	n/a	450 (842)	Al-Cu
11197	WRDC/MLLM	Blank	n/a	450 (842)	Al-Cu
11198	WRDC/MLLM	Blank	n/a	450 (842)	Al-Cu
11199	WRDC/MLLM	Blank	n/a	450 (842)	Al-Cu
11200	WRDC/MLLM	Blank	n/a	450 (842)	Al-Cu
11201	WRDC/MLLM	Blank	n/a	450 (842)	Al-Cu
11202	WRDC/MLLM	10:1	.64 (.25)	482 (900)	Al-Cu
11203	WRDC/MLLM	10:1	.61 (.24)	482 (900)	Al-Cu
11204	WRDC/MLLM	10:1	.64 (.25)	482 (900)	Al-Cu
11205	WRDC/MLLM	10:1	.64 (.25)	482 (900)	Al-Cu
11206	WRDC/MLLM	10:1	.64 (.25)	482 (900)	Al-Cu
11207	Illinois Institute	15.2:1	2.62 (1.03)	1127 (2060)	Ni-Al
11208	Illinois Institute	15.2:1	2.57 (1.01)	1127 (2060)	Ni-Al
11209	WRDC/MLLM	10:1	.64 (.25)	560 (1040)	Al-Cu
11210	McDonnell Douglas	14:1	1.78 (.7)	1343 (2450)	Ti-34Al
11211	McDonnell Douglas	14:1	1.7 (.67)	1343 (2450)	Ti-34Al
11212	McDonnell Douglas	14:1	1.83 (.72)	1343 (2450)	Ti-34Al
11213	McDonnell Douglas	14:1	1.85 (.73)	1343 (2450)	Ti-34Al-1.7Mn
11214	McDonnell Douglas	14:1	1.96 (.77)	1343 (2450)	Ti-34Al-1.7Mn

Billets Processed by Extrusion or Compaction

No.	Source	Die Ratio	Ram Speed cm/s (in/s)	Billet Temp C (F)	Composition
11215	UES	6.5:1	2.08 (.82)	1350 (2462)	Ti-48Al
11216	McDonnell Douglas	14:1	1.91 (.75)	1343 (2450)	Ti-34Al-.94W
11217	McDonnell Douglas	14:1	1.91 (.75)	1343 (2450)	Ti-34Al-.94W
11218	McDonnell Dougl	14:1	1.78 (.7)	1343 (2450)	Ti-34Al-1.44V
11219	McDonnell Douglas	14:1	1.8 (.71)	1343 (2450)	Ti-34Al-1.44V
11220	McDonnell Douglas	10:1	1.5 (.59)	1066 (1950)	Ti-34Al/20V/o-Ti-Nb
11221	WRDC/MLLM	6.3:1	2.03 (.8)	704 (1300)	17-4PH
11222	WRDC/MLLM	16:1	1.14 (.45)	899 (1650)	17-4PH
11223	Metcut	6:1	1.68 (.66)	1204 (2200)	Ti-48.5Al-1Mn-2Nb
11224	WRDC/MLLM	6.1:1	5.31 (2.09)	1191 (2175)	G-2
11225	WRDC/MLLN	6:1	6.35 (2.5)	371 (700)	2024 Al
11226	WRDC/MLLN	17:1	5.66 (2.23)	371 (700)	2024 Al
11227	WRDC/MLLN	6:1	4.83 (1.9)	371 (700)	2024 Al
11228	WRDC/MLLN	6:1	3.99 (1.57)	1649 (3000)	Nb-20Nb5Si3
11229	WRDC/MLLN	6.1:1	3.91 (1.54)	1649 (3000)	Nb-40Nb5Si3
11230	WRDC/MLLN	6:1	4.8 (1.89)	149 (300)	2024 Al
11231	WRDC/MLLN	6:1	5 (1.97)	149 (300)	2024 Al
11232	WRDC/MLLN	17:1	1.51 ips	149 (300)	2024 Al
11233	WRDC/MLLN	17:1	Stuck	149 (300)	2024 Al
11234	WRDC/MLLN	6:1	3.89 (1.53)	371 (700)	2024 Al
11235	WRDC/MLLN	17:1	4.47 (1.76)	149 (300)	2024 Al
11236	Illinois Institute	15.5:1	x	871 (1600)	Ni-Al
11237	Wright State Univ	4.3:1	2.26 (.89)	1760 (3200)	Nb-10Si
11238	Illinois Institute	11:1	2.39 (.94)	260 (500)	Ni-Al
11239	GE/Evendale	20:1	2.69 (1.06)	1316 (2400)	TiAl Gamma
11240	GE/Evendale	20:1	2.59 (1.02)	1316 (2400)	TiAl Gamma
11241	GE/Evendale	20:1	2.01 (.79)	1316 (2400)	TiAl Gamma

Billets Processed by Extrusion or Compaction

No.	Source	Die Ratio	Ram Speed cm/s (in/s)	Billet Temp C (F)	Composition
11242	GE/Evendale	20:1	2.24 (.88)	1316 (2400)	TiAl Gamma
11243	GE/Evendale	20:1	2.29 (.9)	1316 (2400)	TiAl Gamma
11244	GE/Evendale	20:1	2.34 (.92)	1316 (2400)	TiAl Gamma
11245	GE/Evendale	20:1	2.9 (1.14)	1316 (2400)	TiAl Gamma
11246	GE/Evendale	20:1	No data	1371 (2500)	TiAl Gamma
11247	GE/Evendale	20:1	No data	1371 (2500)	TiAl Gamma
11248	GE/Evendale	20:1	2.44 (.96)	1371 (2500)	TiAl Gamma
11249	GE/Evendale	20:1	2.29 (.9)	1371 (2500)	TiAl Gamma
11250	GE/Evendale	20:1	2.21 (.87)	1371 (2500)	TiAl Gamma
11251	McDonnell Douglas	Blank	n/a	399 (750)	Al-15Mn-5Si
11252	McDonnell Douglas	Blank	n/a	399 (750)	Al-15Mn-5Si-Ti-.5B
11253	McDonnell Douglas	Blank	n/a	399 (750)	Al-8.5Fe-1.3V-1.7Si
11254	McDonnell Douglas	Blank	n/a	399 (750)	Al-8.5Fe-1.3V-1.7Si -5Ti-.5B
11255	McDonnell Douglas	19.9:1	1.3 (.51)	399 (750)	Al-15Mn-5Si
11256	McDonnell Douglas	19.9:1	1.17 (.46)	399 (750)	Al-15Mn-5Si-5Ti-.5B
11257	McDonnell Douglas	19.9:1	.91 (.36)	399 (750)	Al-8.5Fe-1.3V-1.7Si
11258	McDonnell Douglas	19.9:1	.89 (.35)	399 (750)	Al-8.5Fe-1.3V-1.7Si -5Ti-.5B
11259	UES	4:1	x	1200 (2192)	Ni-24.1Al-23.4Mo
11260	UES	6:1	1.07 (.42)	1050 (1922)	TiAl G2
11261	UES	6:1	4.39 (1.73)	1150 (2102)	TiAl G2
11262	Westinghouse	6.2:1	1.65 (.65)	900 (1652)	Tungsten/Steel Powder
11263	Westinghouse	6.2:1	2.49 (.98)	900 (1652)	Tungsten/Steel Powder
11264	Westinghouse	6.2:1	2.11 (.83)	900 (1652)	Tungsten/Steel Powder
11265	Westinghouse	6.2:1	0.81 ips	900 (1652)	W

Billets Processed by Extrusion or Compaction

No.	Source	Die Ratio	Ram Speed cm/s (in/s)	Billet Temp C (F)	Composition
11266	Westinghouse	6.2:1	2.11 (.83)	900 (1652)	Tungsten/Steel Powder
11267	Westinghouse	6.2:1	2.16 (.85)	900 (1652)	Tungsten/Steel Powder
11268	Wright State Univ	4.3:1	2.84 (1.12)	1800 (3272)	Nb-15Si
11269	UES	6:1	1.5 (.59)	1150 (2102)	Ti-Al-G-2
11270	UES	6:1	1.6 (.63)	1250 (2282)	Ti-Al-G-2
11271	WRDC/MLLN	6:1	1.5 (.59)	1150 (2102)	Ti-Al (Siltemp.)
11272	UES	6:1	1.91 (.75)	1350 (2462)	TiAl-G-2
11273	WRDC/MLLN	6:1	1.07 (.42)	1050 (1922)	TiAl-G2 (Siltemp)
11274	WRDC/MLLN	6:1	x	1150 (2102)	TiAl-G2
11275	WRDC/MLLN	6:1	x	*Note	Ti-Al
11276	UES	6:1	1.09 (.43)	1150 (2102)	TiAl-G2
11277	Lockheed	15.9:1	1.52 (.6)	225 (437)	Mg-10Al-6Ce-3Zn-2Mn
11278	Lockheed	15.9:1	1.63 (.64)	225 (437)	Mg-10Al-6Ce-3Zn-2Mn
11279	Lockheed	15.9:1	1.75 (.69)	320 (608)	Mg-10Al-6Ce-3Zn-2Mo
11280	Lockheed	15.9:1	1.75 (.69)	320 (608)	Mg-10Al-6Ce-3Zn-2Mn
11281	WRDC/MLLN	6:1	x	899 (1650)	17-4PH Stainless
11282	WRDC/MLLN	6:1	2.72 (1.07)	*Note	TiAl G2
11283	WRDC/MLLN	17:1	1.35 (.53)	816 (1500)	Ti-6-6-2
11284	Metcut	2.18:1	2.06 (.81)	1300 (2372)	Ti-Al (G-87)
11285	UES	6.4:1	2.9 (1.14)	1150 (2102)	Ti-Al (G-2)
11286	UES	6.5:1	4.04 (1.59)	1150 (2102)	TiAl (G-2)
11287	UES	6.4:1	3.81 (1.5)	1150 (2102)	TiAl (G-2)
11288	UES	6.2:1	3.81 (1.5)	1150 (2102)	TiAl (G-2)
11289	UES	6.4:1	4.47 (1.76)	1350 (2462)	TiAl (G-2)
11290	UES	6.5:1	4.42 (1.74)	1350 (2462)	TiAl (G-2)
11291	UES	6.2:1	4.17 (1.64)	1350 (2462)	TiAl (G-2)

Billets Processed by Extrusion or Compaction

No.	Source	Die Ratio	Ram Speed cm/s (in/s)	Billet Temp C (F)	Composition
11292	WRDC/MLLN	6:1	4.45 (1.75)	816 (1500)	Ti-6-6-2
11293	WRDC/MLLN	6:1	2.24 (.88)	816 (1500)	Ti-6-6-2
11294	WRDC/MLLN	6:1	4.75 (1.87)	1038 (1900)	Ti-6-6-2
11295	WRDC/MLLN	6:1	.91 (.36)	1038 (1900)	Ti-6-6-2
11296	WRDC/MLLN	17:1	5.33 (2.1)	1038 (1900)	Ti-6-6-2
11297	WRDC/MLLN	17:1	.84 (.33)	1038 (1900)	Ti-6-6-2
11298	WRDC/MLLN	6:1	4.24 (1.67)	1038 (1900)	Ti-6-6-2
11299	WRDC/MLLN	6:1	.91 (.36)	1038 (1900)	Ti-6-6-2
11300	WRDC/MLLN	17:1	5.18 (2.04)	1038 (1900)	Ti-6-6-2
11301	WRDC/MLLN	17:1	1.4 (.55)	1038 (1900)	Ti-6-6-2
11302	WRDC/MLLN	17:1	2.54 (1)	816 (1500)	Ti-6-6-2
11303	WRDC/MLLN	6:1	.97 (.38)	816 (1500)	Ti-6-6-2
11304	Metcut	6:1	3.66 (1.44)	1343 (2450)	TiAl Gamma
11305	Metcut	6:1	3.66 (1.44)	1343 (2450)	TiAl Gamma
11306	Metcut	6:1	3.78 (1.49)	1343 (2450)	TiAl Gamma
11307	UES	6:1	3.33 (1.31)	1360 (2480)	TiAl
11308	UES	6:1	3.4 (1.34)	1360 (2480)	TiAl
11309	WRDC/MLLN	17:1	3.45 (1.36)	816 (1500)	Ti-6-6-2
11310	WRDC/MLLN	17:1	2.13 (.84)	816 (1500)	Ti-6-6-2
11311	WRDC/MLLN	6:1	4.52 (1.78)	816 (1500)	Ti-6-6-2
11312	UES	6:1	2.95 (1.16)	1150 (2102)	TiAl G2
11313	UES	4:1	4.14 (1.63)	1200 (2192)	Mo Rods
11314	UES	6:1	2.82 (1.11)	1150 (2102)	TiAl G2
11315	UES	6:1	2.77 (1.09)	1150 (2102)	TiAl G2
11316	WRDC/MLLM	9:1	3.61 (1.42)	1038 (1900)	Ti-25Al-10Nb-3V-1Mo
11317	WRDC/MLLM	8.9:1	3.51 (1.38)	1038 (1900)	Ti-25Al-10Nb-3V-1Mo
11318	WRDC/MLLM	8.9:1	3.58 (1.41)	1038 (1900)	Ti-25Al-10Nb-3V-1Mo

Billets Processed by Extrusion or Compaction

No.	Source	Die Ratio	Ram Speed cm/s (in/s)	Billet Temp C (F)	Composition
11319	WRDC/MLLM	8.9:1	3.61 (1.42)	1038 (1900)	Ti-25Al-10Nb-3V-1Mo
11320	Pratt & Whitney	8.9:1	3.2 (1.26)	1052 (1925)	TiAl Gamma
.1321	Pratt & Whitney	8.9:1	3.1 (1.22)	1052 (1925)	TiAl Gamma
11322	Pratt & Whitney	8.9:1	2.82 (1.11)	1010 (1850)	TiAl Gamma
11323	Pratt & Whitney	8.9:1	2.9 (1.14)	1010 (1850)	TiAl Gamma
11324	Pratt & Whitney	8.9:1	3.68 (1.45)	1052 (1925)	TiAl Gamma
11325	Pratt & Whitney	8.9:1	3.63 (1.43)	1052 (1925)	TiAl Gamma
11326	Pratt & Whitney	8.9:1	3.33 (1.31)	1010 (1850)	TiAl Gamma
11327	Pratt & Whitney	8.9:1	1.31 ips	1010 (1850)	TiAl Gamma
11328	WRDC/MLLM	4.3:1	2.84 (1.12)	1349 (2460)	MoSi2
11329	WRDC/MLLM	4.3:1	2.84 (1.12)	1099 (2010)	MoSi2
11330	UES	6:1	5.74 (2.26)	1285 (2345)	TiAl G2
11331	Metcut	6:1	2.46 (.97)	1366 (2490)	TiAl Gamma
11332	Metcut	7:1	2.49 (.98)	1366 (2490)	TiAl Gamma
11333	Metcut	5:1	2.64 (1.04)	1366 (2490)	TiAl Gamma
11334	WRDC/POOX-3	22.3:1	2.51 (.99)	1093 (2000)	Y-Ba-Cu-O
11335	WRDC/MLLM	Blank	n/a	1099 (2010)	MoSi2
11336	WRDC/MLLM	4:1	x	1099 (2010)	MoSi2
11337	UES	3.3:1	3.66 (1.44)	1200 (2192)	Mo Rods & NiAl
11338	WRDC/MLLM	4:1	3.38 (1.33)	1300 (2372)	MoSi2
11339	McDonnell Douglas	14:1	3.25 (1.28)	1343 (2450)	Ti-34Al-4V
11340	McDonnell Douglas	Zr02	2.74 (1.08)	1343 (2450)	Ti-34Al-4V
11341	McDonnell Douglas	14:1	2.21 (.87)	1343 (2450)	Ti-34Al-4V
11342	McDonnell Douglas	14:1	1.83 (.72)	1343 (2450)	Ti-34Al-4V
11343	McDonnell Douglas	14:1	2.03 (.8)	1343 (2450)	Ti-34Al-2Cr-2Mn
11344	McDonnell Douglas	14:1	2.29 (.9)	1343 (2450)	Ti-34Al-2Cr-2Mn
11345	McDonnell Douglas	14:1	3.35 (1.32)	1343 (2450)	Ti-34Al-2Cr-2Mn

Billets Processed by Extrusion or Compaction

No.	Source	Die Ratio	Ram Speed cm/s (in/s)	Billet Temp C (F)	Composition
11346	McDonnell Douglas	14:1	2.46 (.97)	1343 (2450)	Ti34Al-2Cr
11347	UES	6:1	3.07 (1.21)	1200 (2192)	TiAl G2
11348	McDonnell Douglas	10:1	1.93 (.76)	1232 (2250)	Ti-34Al-2Cr
11349	McDonnell Douglas	10:1	2.03 (.8)	1232 (2250)	Ti-34Al-2Cr
11350	UES	6:1	2.51 (.99)	1285 (2345)	TiAl G2
11351	WL/MLLN	6:1	2.79 (1.1)	149 (300)	2024 Al
11352	WL/MLLN	6:1	4.37 (1.72)	149 (300)	2024 Al
11353	WL/MLLN	10:1	Stuck	149 (300)	2024 Al
11354	WL/MLLN	6:1	1.91 (.75)	149 (300)	2024 Al
11355	Pratt & Whitney	10:1	.99 (.39)	982 (1800)	TiAl+Rods
11356	Pratt & Whitney	10:1	6.83 (2.69)	982 (1800)	TiAl+Rods
11357	Pratt & Whitney	10:1	3.61 (1.42)	1800F	TiAl+Rods
11358	Westinghouse	4.2:1	2.82 (1.11)	1000 (1832)	W-LPS
11359	Pratt & Whitney	9.07:1	x	982 (1800)	TiAl+Rods
11360	Pratt & Whitney	9.07:1	3.96 (1.56)	982 (1800)	TiAl+Rods
11361	Pratt & Whitney	9.07:1	x	982 (1800)	TiAl+Rods
11362	Pratt & Whitney	7.02:1	4.01 (1.58)	1010 (1850)	TiAl+Rods
11363	Pratt & Whitney	7.02:1	4.29 (1.69)	1010 (1850)	TiAl+Rods
11364	Westinghouse	3.5:1	3.38 (1.33)	1000 (1832)	W-LPS
11365	WL/MLLN	2.3:1	3.63 (1.43)	149 (300)	2024 Al
11366	WL/MLLN	6.9:1	x	149 (300)	2024 Al
11367	WL/MLLN	6:1	4.45 (1.75)	149 (300)	2024 Al
11368	UES	6:1	5.56 (2.19)	149 (300)	2024 Al
11369	UES	6:1	5.46 (2.15)	149 (300)	2024 Al
11370	WL/MLLN	6.9:1	4.17 (1.64)	149 (300)	2024 Al
11371	McDonnell Douglas	10:1	3.53 (1.39)	1343 (2450)	Ti-34Al-5Nb-3Cr
11372	McDonnell Douglas	10:1	3.68 (1.45)	1343 (2450)	Ti34Al-5Nb-3Cr

Billets Processed by Extrusion or Compaction

No.	Source	Die Ratio	Ram Speed cm/s (in/s)	Billet Temp C (F)	Composition
11373	McDonnell Douglas	10:1	3.15 (1.24)	1343 (2450)	Ti-34Al-5Nb-2Cr
11374	McDonnell Douglas	10:1	2.69 (1.06)	1343 (2450)	Ti-34Al-5Nb-3Cr
11375	WL/MLLN	6.04:1	3.25 (1.28)	*Note	TiAl-G2
11376	McDonnell Douglas	8:1	2.84 (1.12)	1232 (2250)	Ti-34Al-5Nb-3Cr
11377	McDonnell Douglas	8:1	2.13 (.84)	1232 (2250)	Ti-34Al-5Nb-3Cr
11378	McDonnell Douglas	10:1	3.35 (1.32)	1343 (2450)	Ti-34Al-2Cr-2Mn
11379	McDonnell Douglas	10:1	3.56 (1.4)	1343 (2450)	Ti-34Al-2Cr-2Mn
11380	McDonnell Douglas	10:1	3.48 (1.37)	1343 (2450)	Ti-34Al-2Cr-2Mn
11381	UES	6:1	3.1 (1.22)	1050 (1922)	TiAl (G-2)
11382	McDonnell Douglas	14:1	3.56 (1.4)	1343 (2450)	Ti-34Al-3Mn
11383	McDonnell Douglas	14:1	2.82 (1.11)	1343 (2450)	Ti-34Al-3Mn
11384	McDonnell Douglas	14:1	2.87 (1.13)	1343 (2450)	Ti-34Al
11385	McDonnell Douglas	14:1	3.15 (1.24)	1343 (2450)	Ti-34Al
11386	McDonnell Douglas	14:1	3.23 (1.27)	1343 (2450)	Ti34Al-2Cr
11387	McDonnell Douglas	14:1	2.92 (1.15)	1343 (2450)	Ti34Al-.94W
11388	McDonnell Douglas	14:1	3 (1.18)	1343 (2450)	Ti-34Al-1.44V
11389	McDonnell Douglas	14:1	3.1 (1.22)	1343 (2450)	Ti-34Al-1.7Mn
11390	Westinghouse	3.5:1	2.74 (1.08)	1000 (1832)	W-LPS
11391	Westinghouse	3;.5:1	2.74 (1.08)	1000 (1832)	W-LPS
11392	Westinghouse	3.5:1	2.67 (1.05)	1000 (1832)	W-LPS
11393	Westinghouse	33:1	2.77 (1.09)	1000 (1832)	W-LPS
11394	Westinghouse	3.3:1	2.87 (1.13)	1000 (1832)	W-LPS
11395	Westinghouse	3.3:1	3.25 (1.28)	1000 (1832)	W-LPS
11396	Metcut	2.2:1	3.71 (1.46)	1177 (2150)	TiAl
11397	UES	6.3:1	3.4 (1.34)	1380 (2516)	Ti-48Al
11398	Pratt & Whitney	7.2:1	x	996 (1825)	TiAl+Rods
11399	Pratt & Whitney	7.2:1	No data	996 (1825)	TiAl+Rods

Billets Processed by Extrusion or Compaction

No.	Source	Die Ratio	Ram Speed cm/s (in/s)	Billet Temp C (F)	Composition
11400	Pratt & Whitney	7.2:1	No data	996 (1825)	TiAl+Rods
11401	Pratt & Whitney	7.2:1	2.92 (1.15)	996 (1825)	TiAl+Rods
11402	Pratt & Whitney	7.2:1	2.84 (1.12)	996 (1825)	TiAl+Rods
11403	Pratt & Whitney	7.2:1	2.21 (.87)	996 (1825)	TiAl+Rods
11404	Pratt & Whitney	9.6:1	8.71 (3.43)	996 (1825)	TiAl+Rods
11405	Pratt & Whitney	9.6:1	3.38 (1.33)	996 (1825)	TiAl+Rods
11406	Pratt & Whitney	9.6:1	3.28 (1.29)	996 (1825)	TiAl+Rods
11407	Pratt & Whitney	9.6:1	3.51 (1.38)	996 (1825)	TiAl+Rods
11408	Pratt & Whitney	9.6:1	3.4 (1.34)	996 (1825)	TiAl+Rods
11409	UES	6:1	x	1425 (2597)	TiAl-G2
11410	UES	6:1	3.66 (1.44)	260 (500)	2024 Al
11411	UES	6:1	3.58 (1.41)	260 (500)	2024 Al
11412	UES	17:1	3.4 (1.34)	260 (500)	2024 Al
11413	UES	17:1	3.3 (1.3)	260 (500)	2024 Al
11414	UES	4:1	3.84 (1.51)	1200 (2192)	NiAl-23Mo
11415	UES	6:1	3.43 (1.35)	260 (500)	2024 Al
11416	UES	6:1	3.2 (1.26)	260 (500)	2024 Al
11417	Metcut	2.4:1	3.91 (1.54)	1300 (2372)	TiAl Gamma
11418	Metcut	2.4:1	3.81 (1.5)	1300 (2372)	TiAl Gamma
11419	Metcut	6:1	3.28 (1.29)	1350 (2462)	TiAl Gamma
11420	UES	6:1	3.48 (1.37)	1370 (2498)	Ti-48Al-2Cr-2Nb
11421	UES	6:1	3.15 (1.24)	1370 (2498)	Ti48Al-2Cr-2Nb
11422	UES	6.9:1	3.56 (1.4)	1149 (2100)	410 Stainless Steel
11423	UES	6.9:1	3.68 (1.45)	1149 (2100)	410 Stainless Steel
11424	UES	6:1	3.89 (1.53)	1149 (2100)	Ti-6-2-4-2
11425	UES	6:1	3.05 (1.2)	1390 (2534)	Ti-48Al

Billets Processed by Extrusion or Compaction

No.	Source	Die Ratio	Ram Speed cm/s (in/s)	Billet Temp C (F)	Composition
11426	UES	6:1	1.55 (.61)	1150 (2102)	TiAl G-2 (Heat Treated)
11427	UES	6:1	3.48 (1.37)	260 (500)	2024 Al
11428	UES	17:1	No data	260 (500)	2024 Al
11429	UES	7.13:1	3.99 (1.57)	1149 (2100)	TI-6-2-4-2
11430	UES	7.13:1	11.28 (4.44)	1149 (2100)	TI-6-6-2
11431	UES	17:1	2.95 (1.16)	260 (500)	2024 Al
11432	UES	17:1	2.84 (1.12)	260 (500)	2024 Al
11433	Allison-Campbell	5.7:1	2.92 (1.15)	1316 (2400)	TiAl
11434	Allison-Campbell	5.7:1	2.26 (.89)	1316 (2400)	TiAl
11435	Allison-Campbell	5.7:1	.86 (.34)	1316 (2400)	TiAl
11436	Allison-Campbell	5.7:1	2.39 (.94)	1316 (2400)	TiAl
11437	Allison-Campbell	5.7:1	No data	1371 (2500)	TiAl
11438	Allison-Campbell	5.7:1	2.57 (1.01)	1371 (2500)	TiAl
11439	Allison-Campbell	5.76:1	2.67 (1.05)	1316 (2400)	TiAl
11440	Allison-Campbell	5.76:1	2.82 (1.11)	1316 (2400)	TiAl
11441	Allison-Campbell	5.76:1	2.84 (1.12)	1371 (2500)	TiAl
11442	Allison-Campbell	5.76:1	2.95 (1.16)	1371 (2500)	TiAl
11443	Allison-Campbell	5.76:1	2.79 (1.1)	1371 (2500)	TiAl
11444	Allison-Campbell	5.76:1	2.97 (1.17)	1371 (2500)	TiAl
11445	Allison-Campbell	5.76:1	2.95 (1.16)	1371 (2500)	TiAl
11446	Allison-Campbell	5.76:1	3.18 (1.25)	1343 (2450)	TiAl
11447	WL/MLLN	6:1	3.05 (1.2)	816 (1500)	Ti-6-6-2
11448	WL/MLLN	6:1	9.63 (3.79)	816 (1500)	Ti-6-6-2
11449	WL/MLLN	6:1	4.45 (1.75)	816 (1500)	Ti-6-6-2
11450	WL/MLLN	6:1	1.65 (.65)	816 (1500)	Ti-6-6-2
11451	WL/MLLN	17:1	3.33 (1.31)	816 (1500)	Ti-6-6-2

Billets Processed by Extrusion or Compaction

No.	Source	Die Ratio	Ram Speed cm/s (in/s)	Billet Temp C (F)	Composition
11452	WL/MLLN	17:1	4.22 (1.66)	816 (1500)	Ti-6-6-2
11453	WL/MLLN	17:1	5.23 (2.06)	816 (1500)	Ti-6-6-2
11454	WL/MLLN	6:1	6.45 (2.54)	816 (1500)	Ti-6-6-2
11455	WL/MLLN	6:1	4.04 (1.59)	816 (1500)	Ti-6-6-2
11456	UES	6:1	2.84 (1.12)	1435 (2615)	TiAl G-2 (Siltemp)
11457	WL/MLLN	6:1	4.04 (1.59)	1038 (1900)	Ti-6-6-2
11458	WL/MLLN	17:1	1.65 (.65)	1038 (1900)	Ti-6-6-2
11459	WL/MLLN	17:1	3.66 (1.44)	816 (1500)	Ti-6-6-2
11460	McDonnell Douglas	14:1	3.68 (1.45)	1066 (1950)	Ti-7.5Al-4V
11461	McDonnell Douglas	14:1	3.71 (1.46)	1066 (1950)	Ti-6Al
11462	McDonnell Douglas	14:1	3.73 (1.47)	1066 (1950)	Ti-5.5Al-4V-.5B
11463	McDonnell Douglas	14:1	3.73 (1.47)	1066 (1950)	Ti-7Al-4V-.5B
11464	McDonnell Douglas	14:1	3.86 (1.52)	1066 (1950)	Ti-6Al-4V
11467	UES	6:1	2.06 (.81)	1150 (2102)	TiAl G2
11468	UES	6:1	2.06 (.81)	1150 (2102)	TiAl G2
11469	UES	6:1	x	1150 (2102)	TiAl G2
11470	UES	6:1	4.95 (1.95)	1170 (2138)	TiAl G2
11471	UES	6:1	2.9 (1.14)	1170 (2138)	TiAl G2
11472	UES	6:1	2.97 (1.17)	1170 (2138)	TiAl G2
11473	UES	6:1	x	1170 (2138)	TiAl G2
11474	UES	6.3:1	3.53 (1.39)	1250 (2282)	TiAl G2
11475	UES	6:1	3.07 (1.21)	1250 (2282)	TiAl G2
11476	UES	6:1	3.25 (1.28)	1250 (2282)	TiAl G2
11477	UES	4:1	3.58 (1.41)	1200 (2192)	NiAl Powder+Mo Rods
11478	UES	6:1	2.24 (.88)	1170 (2138)	TiAl G2
11479	UES	6:1	2.74 (1.08)	1170 (2138)	TiAl G2
11480	UES	6:1	2.67 (1.05)	1170 (2138)	TiAl G2

Billets Processed by Extrusion or Compaction

No.	Source	Die Ratio	Ram Speed cm/s (in/s)	Billet Temp C (F)	Composition
11481	UES	6:1	3.86 (1.52)	1425 (2597)	TiAl G2
11482	UES	6:1	2.57 (1.01)	1380 (2516)	Ti-48Al-2Cr-2Nb
11483	UES	6:1	3.2 (1.26)	1250 (2282)	TiAl G2
11484	UES	6:1	3.02 (1.19)	1250 (2282)	TiAl G2
11485	UES	6:1	2.95 (1.16)	1250 (2282)	TiAl G2
11486	UES	5.8:1	3.43 (1.35)	1370 (2498)	TiAl
11487	UES	5.8:1	3.43 (1.35)	2498F/2552F	TiAl

APPENDIX B: LIST OF EVACUATION AND OUTGASSING OPERATIONS

Evacuation and Outgassing Operations

Batch No.	Source	Number of Cans	Can Material	Can Type	Material Type	Material Class
536	Martin Mariett-	3	Ti	Extrusion	Powder	TiAl
537	Martin Marietta	2	Mild Steel	Extrusion	Powder	Cu
538	Martin Marietta	2	Mild Steel	Extrusion	Powder	Cu
539	Metcut	4	Mild Steel	HIP	Powder	Ti
540	Metcut	4	Mild Steel	HIP	Powder	Ti
541	Metcut	4	Mild Steel	HIP	Powder	Ti
542	Metcut	4	Mild Steel	HIP	Powder	Ti
543	Metcut	1	Mild Steel	HIP	Ingot	TiAl
544	Metcut	2	Mild Steel	HIP	Powder	Ti
545	Metcut	3	Mild Steel	HIP	Powder	TiAl
546	Metcut	1	SS	Extrusion	Ingot	TiAl
547	McDonnell Douglas	4	SS	Extrusion	Powder	TiAl
548	McDonnell Douglas	4	SS	Extrusion	Powder	TiAl
549	Martin Marietta	2	Ti	Extrusion	Powder	TiAl
550	Martin Marietta	4	Ti	Extrusion	Powder	TiAl
551	Martin Marietta	4	Ti	Extrusion	Powder	TiAl
552	Martin Marietta	2	Ti	Extrusion	Powder	TiAl
553	McDonnell Douglas	4	Ti	Extrusion	Ingot	TiAl
554	McDonnell Douglas	2	Ti	Extrusion	Ingot	TiAl
555	Metcut	2	Mild Steel	HIP	Powder	Nb
556	McDonnell Douglas	2	Ti	Extrusion	Powder	TiAl
557	McDonnell Douglas	3	Ti	Extrusion	Powder	TiAl
558	MLLM	2	Ti	Extrusion	Powder	TiAl
559	Metcut	4	Mild Steel	HIP	Powder	Ti
560	Metcut	2	Mild Steel	HIP	Powder	Ti
561	Metcut	2	SS	Extrusion	Powder	TiAl
562	MLLM	2	SS	Extrusion	Powder	TiAl

Evacuation and Outgassing Operations

Batch No.	Source	Number of Cans	Can Material	Can Type	Material Type	Material Class
563	McDonnell Douglas	4	Ti	Extrusion	Powder	Ti
564	McDonnell Douglas	4	Ti	Extrusion	Powder	Ti
565	McDonnell Douglas	4	Ti	Extrusion	Powder	Ti
566	Metcut	2	Mild Steel	HIP	Powder	TiAl
567	Metcut	4	Mild Steel	Extrusion	Powder	Ti
568	Metcut	3	Mild Steel	HIP	Powder	Ti
569	Metcut	3	SS;Ti	Extrusion	Powder	TiAl
570	Garrett	4	Ti	Extrusion	Powder	TiAl
571	Garrett	2	Ti	Extrusion	Powder	TiAl
572	Garrett	4	Ti	Extrusion	Powder	TiAl
573	Garrett	3	Ti	Extrusion	Powder	TiAl
574	UES	1	SS	Extrusion	Ingot	Ni
575	McDonnell Douglas	4	Ti	Extrusion	Powder	TiAl
576	Metcut	1	Ti	Extrusion	Ingot	TiAl
577	UES	2	SS	Extrusion	Ingot	Ni
578	MLLS	4	Ti	Extrusion	Powder	TiAl
579	Metcut	2	Mild Steel	HIP	Other	
580	McDonnell Douglas	4	Ti	Extrusion	Powder	TiAl
581	McDonnell Douglas	1	Ti	Extrusion	Powder	TiAl
582	McDonnell Douglas	1	Al	Extrusion	Powder	Al
583	Metcut	4	SS	HIP	Powder	TiAl
584	Metcut	4	SS	Forge		TiAl
585	Metcut	4	SS	Forge		TiAl
586	Metcut	4	SS	Forge		TiAl
587	McDonnell Douglas	4	Ti	Extrusion	Powder	TiAl
588	UES	4	Ti	Heat Treat	Ingot	Nb
589	UES	2	Ti	Heat Treat	Ingot	Nb

Evacuation and Outgassing Operations

Batch No.	Source	Number of Cans	Can Material	Can Type	Material Type	Material Class
590	Metcut	5	Mild Steel	HIP	Powder	Ti
591	Metcut	1	Mild Steel	HIP	MMC	Ti
592	Metcut	2	Mild Steel	HIP	MMC	Ti
593	Metcut	3	SS;Ti	Extrusion	Ingot	TiAl
594	UES	1	SS	Extrusion	Ingot	Ni
595	Metcut	3	Mild Steel	HIP	MMC	Ti
596	UES	1	SS	Extrusion	Ingot	Ni
597	Metcut	3	Mild Steel	HIP	MMC	Ti
598	Metcut	2	Ti	HIP	Powder	Ti
599	Metcut	4	Mild Steel	HIP	MMC	Ti
600	Metcut	1	Mild Steel	HIP	MMC	Ti
601	Illinois Institute	2	SS	Extrusion	Powder	NiAl
602	Metcut	4	Ti	HIP	Powder	
603	WRDC/POOX-3	2	Ag	Rolling	Powder	Ni
604	Metcut	4	Ti	HIP	Powder	
605	UES	2	SS	Extrusion	Ingot	TiAl
606	Metcut	4	Ti	HIP	Powder	
607	MLLM	2	SS	Extrusion	Ingot	TiAl
608	Metcut	4	Ti	HIP	Powder	CRGA
609	Metcut	4	Ti	Extrusion	Ingot	TiAl
610	Metcut	4		HIP	Other	Ti
611	UES	1	Ti	Extrusion		
612	Metcut	4	Mild Steel	HIP	MMC	Ti
613	UES	1	Ti	Extrusion	Powder	Al
614	MLLM	5	Al	Extrusion	Powder	Al
615	McDonnell Douglas	4	Ti	Extrusion	Ingot	TiAl
616	Metcut	4	SS	HIP	Powder	TiAl

Evacuation and Outgassing Operations

Batch No.	Source	Number of Cans	Can Material	Can Type	Material Type	Material Class
617	Metcut	2	SS	HIP	Powder	TiAl
618	Metcut	2	SS	HIP	Powder	TiAl
619	Metcut	2	SS	HIP	Powder	TiAl
620	Metcut	2	SS	HIP	Powder	TiAl
621	Illinois Institute	2	SS	Extrusion	Ingot	TiAl
622	Metcut	2	SS	HIP	Powder	TiAl
623	McDonnell Douglas	4	Ti	Extrusion	Ingot	TiAl
624	McDonnell Douglas	4	Ti	Extrusion	Ingot	TiAl
625	Metcut	4	Mild Steel	HIP	MMC	Ti
626	McDonnell Douglas	4	SS;Ti	Extrusion	Powder	TiAl
627	UES	3	Ti	Heat Treat	Ingot	TiAl
628	MLLM	4	Al	Extrusion	Powder	Al
629	Metcut	4	Mild Steel	HIP	MMC	Ti
630	MLLM	3	SS	Extrusion	Ingot	TiAl
631	Metcut	1	SS	Extrusion	Ingot	TiAl
632	MLLM	1	SS	Extrusion	Ingot	TiAl
633	MLLM	2	SS	Extrusion	Ingot	TiAl
634	Illinois Institute	2	SS	Extrusion	Ingot	TiAl
635	Metcut	2	Mild Steel	HIP	MMC	Ti
636	Metcut	1	Ti	HIP	Powder	TiAl
637	McDonnell Douglas	4	Al	Extrusion	Powder	Al
638	UES	4	Ti:SS	Extrusion	Ingot	TiAl
639	UES	2	Ti	Extrusion	Ingot	TiAl
640	UES	3	Ti:SS	Extrusion	Ingot	TiAl
641	Metcut	3	Ti	HIP	Powder	TiAl
642	Lockheed	3	Al	Extrusion	Powder	Mg
643	Lockheed	1	Al	Extrusion	Powder	Mg

Evacuation and Outgassing Operations

Batch No.	Source	Number of Cans	Can Material	Can Type	Material Type	Material Class
644	Metcut	1	Mild Steel	HIP	MMC	Ti
645	Metcut	2	SS:Ti	Extrusion	Powder	TiAl
646	Metcut	2	Mild Steel	HIP	MMC	Ti
647	UES	3	SS	Extrusion	Ingot	TiAl
648	UES	3	SS	Extrusion	Ingot	TiAl
649	UES	3	Ti	Extrusion	Ingot	TiAl
650	Metcut	2	Mild Steel	HIP	Powder	TiAl
651	UES	1	SS	Extrusion	Powder	TiAl
652	Metcut	2	Mild Steel	HIP	Other	Ti
653	Metcut	3	Ti	Extrusion	Ingot	TiAl
654	UES	1	SS	Extrusion	Ingot	TiAl
655	UES	1	B-21S	Extrusion	Ingot	TiAl
656	UES	2	SS	Extrusion	Powder	MoSi2
657	Metcut	3	Ti	Extrusion	Ingot	TiAl
658	MLLM	1	SS	Extrusion	Powder	MoSi2
659	McDonnell Douglas	4	Ti	Extrusion	Ingot	TiAl
660	McDonnell Douglas	4	Ti	Extrusion	Ingot	TiAl
661	McDonnell Douglas	3	Ti	Extrusion	Ingot	TiAl
662	Metcut	4	Ti	HIP	Powder	TiAl
663	Metcut	2	Mild Steel	HIP	Powder	TiAl
664	UES	1	SS	Extrusion	Ingot	Ni
665	UES	1	Ti	Extrusion	Ingot	TiAl
666	MLLM	3	Ti	Heat Treat	Powder	Ti
667	Metcut	4	Mild Steel	HIP	Other	TiAl
668	McDonnell Douglas	17	Ti	Extrusion	Ingot	TiAl
669	UES	1	SS	Extrusion	Ingot	TiAl
670	MLBT	5	Mild Steel	HIP		

Evacuation and Outgassing Operations

Batch No.	Source	Number of Cans	Can Material	Can Type	Material Type	Material Class
671	MLBT	5	Mild Steel	HIP		
672	Metcut	2	Mild Steel	HIP	Powder	TiAl
673	Metcut	3	Mild Steel	HIP	Powder	Ti
674	Metcut	1	SS	Extrusion	Ingot	TiAl
675	Metcut	3	Mild Steel	HIP	Other	Ti
676	Metcut	1	Mild Steel	HIP	Ingot	TiAl
677	UES	4	Ti	Heat Treat	Ingot	TiAl
678	UES	3	Ti	Heat Treat	Ingot	TiAl
679	Metcut	2	Mild Steel	HIP	Other	Ti
680	Metcut	1	Mild Steel	HIP	Powder	TiAl
681	UES	4	Ti	Heat Treat	Ingot	TiAl
682	MLLM	2	Mild Steel	HIP	Other	Ti
683	MLLM	1	Mild Steel	HIP	Other	Ti
684	UES	1	Ti	Extrusion	Ingot	TiAl
685	Metcut	1	Mild Steel	HIP	Powder	Al
686	UES	1	Ti	Extrusion	Ingot	TiAl
687	MLLM	1	Mild Steel	HIP	Ingot	Ti
688	MLLM	4	Mild Steel	HIP	Ingot	Ti
689	MLLM	1	Mild Steel	HIP	Ingot	Ti
690	MLLM	5	Mild Steel	HIP	Ingot	Ti
691	Metcut	3	Mild Steel	HIP	Powder	TiAl
692	MLLM	1	Mild Steel	HIP	Ingot	Ti
693	Metcut	3	Ti	Extrusion	Ingot	TiAl
694	UES	1	SS	Extrusion	Ingot	TiAl
695	MLLM	1	Mild Steel	HIP	Powder	Ti
696	Metcut	5	Mild Steel	HIP	MMC	Ti
697	Allison	6	Ti	Extrusion	Ingot	TiAl

Evacuation and Outgassing Operations

Batch No.	Source	Number of Cans	Can Material	Can Type	Material Type	Material Class
698	Metcut	2	Mild Steel	HIP	MMC	Ti
699	Metcut	2	Mild Steel	HIP	MMC	Ti
700	Allison	2	Ti	Extrusion	Ingot	TiAl
701	UES	1		Extrusion	Ingot	TiAl
702	Allison	6	Ti	Extrusion	Ingot	TiAl
703	Metcut	10	Mild Steel	HIP	MMC	Ti
704	McDonnell Douglas	5	Ti	Extrusion	Powder	Ti
705	UES	5	SS	Extrusion	Ingot	TiAl
706	UES	2	SS	Extrusion	Ingot	TiAl
707	UES	3	SS	Extrusion	Ingot	TiAl
708	UES	1	Ti	Heat Treat	Ingot	TiAl
709	UES	3	SS	Extrusion	Ingot	TiAl

APPENDIX C: LIST OF VACUUM ARC MELT OPERATIONS

Vacuum Arc Melting Operations (Button Melts)

Melt No.	Source Agency	Source Person	Class	Target Composition
130	UES	P. R. Subramanian	Nb	Nb-33.5Mo-25.9Al
131	UES	P. R. Subramanian	Nb	Nb-26.0Al-23.5Mo
132	UES	P. R. Subramanian	Al	Al-30.5Mo-29.5Nb
133	UES	P. R. Subramanian	Nb	Nb-29.44W-25.92Al
134	UES	P. R. Subramanian	W	W-26.0Nb-22.6Al
135	UES	P. R. Subramanian	W	W-31.3Al-23.1Nb
136	UES	P. R. Subramanian	Nb	Nb-46.5Al-4.4Mo
137	UES	P. R. Subramanian	Al	Al-44.8Nb-8.8Mo
138	UES	P. R. Subramanian	Nb	Nb-29.3Al-22.9Mo
139	UES	P. R. Subramanian	Al	Al-33.7Mo-32.6Nb
140	UES	P. R. Subramanian	Nb	Nb-46.56Al
141	UES	P. R. Subramanian	Nb	Nb-45.7Al-1.2Cr
142	UES	P. R. Subramanian	Nb	Nb-32.2W-32.1Al
143	UES	P. R. Subramanian	Nb	Nb-33.5Mo-25.9Al
144	UES	P. R. Subramanian	Nb	Nb-33.5Mo-25.9Al
145	UES	P. R. Subramanian	Nb	Nb-33.5Mo-25.9Mo
146	UES	P. R. Subramanian	Nb	Nb-33.5Mo-25.9Al
147	UES	P. R. Subramanian	Nb	Nb-26.0Al-23.5Mo
148	UES	P. R. Subramanian	Nb	Nb-26.0Al-23.5Mo
149	UES	P. R. Subramanian	Nb	Nb-26.0Al-23.5Mo
150	UES	P. R. Subramanian	Nb	Nb-26.0Al-23.5Mo
151	UES	P. R. Subramanian	Al	Al-30.5Mo-29.5Nb
152	UES	P. R. Subramanian	Al	Al-30.5Mo-29.5Nb
153	UES	P. R. Subramanian	Al	Al-30.5Mo-29.5Nb
154	UES	P. R. Subramanian	Al	Al-30.5Mo-29.5Nb
155	UES	P. R. Subramanian	Nb	Nb-29.44W-25.92Al
156	UES	P. R. Subramanian	Nb	Nb-29.44W-25.9Al

Vacuum Arc Melting Operations (Button Melts)

Melt No.	Source Agency	Source Person	Class	Target Composition
157	UES	P. R. Subramanian	Nb	Nb-29.44W-25.92Al
158	UES	P. R. Subramanian	Nb	Nb-29W
159	UES	P. R. Subramanian	W	W-26.0Nb-22.6Al
160	UES	P. R. Subramanian	W	W-26.0Nb-22.6Al
161	UES	P. R. Subramanian	W	W-26.0Nb-22.6Al
162	UES	P. R. Subramanian	W	W-26.0Nb-22.6Al
163	UES	P. R. Subramanian	W	W-31.3Al-23.1Nb
164	UES	P. R. Subramanian	W	W-31.3Al-23.1Nb
165	UES	P. R. Subramanian	W	W-31.3Al-23.1Nb
166	UES	P. R. Subramanian	W	W-31.3Al-23.1Nb
167	MLLM	Siamack	Cr	Cr-25Hf
168	MLLM	Siamack	Cr	Cr-53.36Hf
169	MLLM	Siamack	Cr	Cr-25Zr
170	MLLM	Siamack	Cr	Cr-36Zr
171	MLLM	Siamack	Al	Al-41.89Ti-3.31Fe
172	MLLM	Siamack	Al	Al-46.41Ti-4.41Fe
173	UES	Madan Mendiratta	Nb	Nb-38.5Si
174	UES	K. Williams	TiAl	Ti-15Al-16Nb
175	UES	K. Williams	TiAl	Ti-13Al-19Nb
176	UES	K. Williams	TiAl	Ti-10Al-29Nb
177	UES	K. Williams	TiAl	Ti-5Al-42Nb
178	MLLM	Dan Miracle	Cr	Cr-4.2Si
179	MLLM	Dan Miracle	Cr	Cr-4.3Si
180	MLLM	Dan Miracle	Cr	Cr-4.4Si
181	MLLM	Dan Miracle	Cr	Cr-4.5Si
182	MLLM	Dan Miracle	Cr	Cr-4.7Si
183	UES	Madan Mendiratta	Nb	Nb-15.4Si

Vacuum Arc Melting Operations (Button Melts)

Melt No.	Source Agency	Source Person	Class	Target Composition
184	UES	P. R. Subramanian	Nb	Nb-45.1Al-8.7Mo
185	UES	P. R. Subramanian	Nb	Nb-45.1Al-8.7Mo
186	UES	P. R. Subramanian	Nb	Nb-45.4Al-1.2Cr
187	UES	P. R. Subramanian	Nb	Nb-45.4Al-1.2Cr
188	UES	P. R. Subramanian	Al	Al-41.0Cr-25.0Nb
189	UES	P. R. Subramanian	Cr	Cr-34.0Al-25.0Nb
190	UES	P. R. Subramanian	Nb	Nb-45.4Al-1.3Ni
191	UES	P. R. Subramanian	Nb	Nb-45.4Al-1.3Ni
192	UES	P. R. Subramanian	Nb	Nb-32.2W-32.1Al
193	UES	P. R. Subramanian	Nb	Nb-32.2W-32.1Al
194	UES	P. R. Subramanian	Nb	Nb-35.0Al-27.2W
195	UES	P. R. Subramanian	Nb	Nb-35.0Al-27.2W
196	UES	P. R. Subramanian	Nb	Nb-39.9Al-18.6W
197	UES	P. R. Subramanian	Nb	Nb-39.9Al-18.6W
198	UES	P. R. Subramanian	Nb	Nb-41.4Al-5.7Cr-4.0W-2.0Y
199	UES	P. R. Subramanian	Nb	Nb-41.4Al-5.7Cr-4.0W-2.0Y
200	MLLM	Dan Miracle	Ta	Ta-13Si
201	MLLM	Dan Miracle	Ta	Ta-30Si
202	UES	P. R. Subramanian	Cr	Cr-20.9Al-.8Nb
203	UES	P. R. Subramanian	W	W-10.7Nb-1.2Al
204	UES	P. R. Subramanian	Nb	Nb-46.0Al
205	UES	P. R. Subramanian	Nb	Nb-46.0Al
206	UES	P. R. Subramanian	Nb	Nb-46.0Al
207	UES	Tom Goff	Ti	CP-Ti
208	UES	Tom Goff	Ti	CP-Ti
209	MLLM	Dan Miracle	Ta	Ta-2Si
210	MLLM	Dan Miracle	Ta	Ta-6Si

Vacuum Arc Melting Operations (Button Melts)

Melt No.	Source Agency	Source Person	Class	Target Composition
211	UES	P. R. Subramanian	Cr	Cr-34.0Al-25.0Nb
212	UES	Tom Goff	Ti	Ti-Sponge
213	Metcut	Y. Kim	TiAl	Ti-33.33Al
214	Metcut	Y. Kim	TiAl	Ti-33.39Al-4.74Sc
215	Metcut	Krishnamurthy	TiAl	Ti-34.09Al-4.03V
216	Metcut	Krishnamurthy	TiAl	Ti-34.09Al-4.03V
217	Metcut	Krishnamurthy	TiAl	Ti-34.04Al-2.89Mn
218	Metcut	Krishnamurthy	TiAl	Ti-34.04Al-2.89Mn
219	MLLM	Joe Newkirk	Cr	Cr-3Si
220	MLLM	Joe Newkirk	Cr	Cr-7Si
221	Metcut	Krishnamurthy	TiAl	Ti-33.31Al-3.93V-4.28Nb
222	Metcut	Krishnamurthy	TiAl	Ti-33.31Al-3.94V-4.28Nb
223	UES	P. R. Subramanian	NiAl	Ni-93Al-18Re
224	UES	P. R. Subramanian	NiAl	Ni-25.8Al-18.1Mo
225	UES	P. R. Subramanian	NiAl	Ni-25.8Al-18.1Mo
226	WSU	Harry Lipsitt	TiAl	Ti-13.3Al-21.1Nb-2.4Ni-2Mo
227	WSU	Harry Lipsitt	TiAl	Ti-13.3Al-19.1Nb-2.4Ni-4Mo
228	WSU	Harry Lipsitt	TiAl	Ti-13.3Al-21.1Nb-6.1Co
229	WSU	Harry Lipsitt	TiAl	Ti-13.3Al-20.9Nb-6Co-2Mo
230	WSU	Harry Lipsitt	TiAl	Ti-13.2Al-20.8Nb-6.4Cu-2Mo
231	WSU	Harry Lipsitt	TiAl	Ti-13.3Al-21.1Nb-5.4Cr-2Mo
232	WSU	Harry Lipsitt	TiAl	Ti-13.4Al-21Nb-6.5Cu
233	WSU	Harry Lipsitt	TiAl	Ti-27Al-5Nb-5Zr
234	WSU	Harry Lipsitt	TiAl	Ti-29.8Al
235	WSU	Harry Lipsitt	TiAl	Ti-36Al
236	UES	Vijay Shende	TiAl	Ti-36.242Al-4.364Er
237	UES	Vijay Shende	TiAl	Ti-34.48Al-4.32Er

Vacuum Arc Melting Operations (Button Melts)

Melt No.	Source Agency	Source Person	Class	Target Composition
238	UES	Vijay Shende	TiAl	Ti-32.75Al-4.27Er
239	WSU	Harry Lipsitt	TiAl	Ti-32.4Al
240	WSU	Harry Lipsitt	TiAl	Ti-28.1Al
241	WSU	Harry Lipsitt	TiAl	Ti-24.9Al
242	WSU	Harry Lipsitt	TiAl	Ti-24.9Al
243	WSU	Harry Lipsitt	TiAl	Ti-23.3Al
244	WSU	Harry Lipsitt	TiAl	Ti-36.03Al
245	UES	P. R. Subramanian	Al	Al-1.9-.1Nb
246	UES	P. R. Subramanian	Al	Al-1.9-.1Nb
247	UES	P. R. Subramanian	Al	Al-4.75Nb
248	UES	P. R. Subramanian	Al	Al-4.75Nb
249	UES	P. R. Subramanian	Cr	Cr-20.9Al-.8Nb
250	UES	P. R. Subramanian	Cr	Cr-20.9Al-.8Nb
251	UES	P. R. Subramanian	W	W-7.1Nb-1.9Al
252	UES	P. R. Subramanian	W	W-7.1Nb-1.9Al
253	UES	Tom Goff	Ti	Ti-Sponge
254	Metcut	Y. Kim	TiAl	Ti-25Al
255	Metcut	Y. Kim	TiAl	Ti-34Al
256	Metcut	Y. Kim	TiAl	Ti-40Al
257	Metcut	Y. Kim	TiAl	Ti-43Al
258	Metcut	Y. Kim	TiAl	Ti-46Al
259	Metcut	Y. Kim	TiAl	Ti-48Al
260	Metcut	Y. Kim	TiAl	Ti-49Al
261	Metcut	Y. Kim	TiAl	Ti-50Al
262	Metcut	Y. Kim	TiAl	Ti-51Al
263	Metcut	Y. Kim	TiAl	Ti-53Al
264	Metcut	Y. Kim	TiAl	Ti-55Al

Vacuum Arc Melting Operations (Button Melts)

Melt No.	Source Agency	Source Person	Class	Target Composition
265	Metcut	Y. Kim	TiAl	Ti-57Al
266	UES	Vijay Shende	TiAl	Ti-27.53-Al-19.5
267	UES	Tom Goff	Ti	Ti-Sponge
268	UES	Tom Goff	Ti	Ti-Sponge
269	UES	Tom Goff	Ti	Ti-Sponge
270	UES	Tom Goff	Ti	Ti-Sponge
271	UES	Tom Goff	Ti	Ti-Sponge
272	UES	Bob Sweeney	NiAl	Ni-2.58Al-18.1Mo
273	UES	Bob Sweeney	NiAl	Ni-2.58Al-18.1Mo
274	UES	Bob Sweeney	W	W-7.1Nb-1.9Al
275	UES	P. R. Subramanian	Cr	Cr-34.0Al-25.0Nb
276	MLLM	Siamack	W	W-21.47Nb-2.91Mo-2.47Zr
277	MLLM	Siamack	W	W-23.99Nb-3.91Mo
278	MLLM	Siamack	Cr	Cr-8.63Ti-5.0Al-2.0Ni
279	MLLM	Siamack	Cr	Cr-8.63Ti-5.0Al-1.99Mn
280	MLLS	Tom Broderick	TiAl	Ti-6.48Al-31.39Nb-13.14V-7.68Mo
281	MLLS	Tom Broderick	TiAl	Ti-14.01Al-17.73Nb-3.2V-7.02Mo
282	MLLS	Tom Broderick	TiAl	Ti-5.12Al-32.07Nb-13.19V-9.94Mo
283	MLLS	Tom Broderick	TiAl	Ti-5.21Al-32.59Nb-14.3V-6.73Mo
284	MLLS	Tom Broderick	TiAl	Ti-14.84Al-16.03Nb-3.30V-.41Mo
285	MLLS	Tom Broderick	TiAl	Ti-14.84Al-16.03Nb-3.30V-.41Mo
286	UES	P. R. Subramanian	Ni	Ni-26.7Al-15.3Re
287	UES	P. R. Subramanian	Ni	Ni-26.7Al-15.3Re
288	MLLM	Siamack	Al	Al-35.19Ti-20.75Cu
289	UES	P. R. Subramanian	Al	Al-34.75Ti-12.76Mn
290	UES	P. R. Subramanian	Al	Al-34.99Ti-12.16Cr
291	UES	P. R. Subramanian	Al	Al-34.43Ti-13.56Co

Vacuum Arc Melting Operations (Button Melts)

Melt No.	Source Agency	Source Person	Class	Target Composition
292	UES	P. R. Subramanian	Al	Al-34.43Ti-13.56Co
293	UES	P. R. Subramanian	NiAl	Ni-38.21-Al-17.57
294	UES	P. R. Subramanian	NiAl	Ni-34.72-Al-15.96
295	UES	P. R. Subramanian	V	V-38.21Ni-17.57Al
296	UES	P. R. Subramanian	V	V-34.72Ni-15.96Al
297	UES	P. R. Subramanain	V	V-38.21Ni-17.57Al
298	UES	P. R. Subramanian	V	V-34.72Ni-15.96Al
299	UES	P. R. Subramanian	V	V-31.29Ni-14.39Al
300	UES	P. R. Subramanian	V	V-38.21Ni-17.57Al
301	Metcut	Y. Kim	TiAl	Ti-15.7Al
302	Metcut	Y. Kim	TiAl	Ti-23.4Al
303	Metcut	Y. Kim	TiAl	Ti-33.3Al
304	Metcut	Y. Kim	TiAl	Ti-36.9Al
305	Metcut	Y. Kim	TiAl	Ti-29.8Al
306	Metcut	Y. Kim	TiAl	Ti-31.6Al
307	Metcut	Y. Kim	TiAl	Ti-37.9Al
308	Metcut	Y. Kim	TiAl	Ti-37.9Al
309	Metcut	Y. Kim	TiAl	Ti-15.7Al-1.7TiO2
310	Metcut	Y. Kim	TiAl	Ti-15.6Al-6.7TiO2
311	Metcut	Y. Kim	TiAl	Ti-15.4Al-18.3TiO2
312	Metcut	Y. Kim	TiAl	Ti-23.4Al-1.7TiO2
313	Metcut	Y. Kim	TiAl	Ti-13.3Al-6.7TiO2
314	Metcut	Y. Kim	TiAl	Ti-23.1Al-18.3TiO2
315	Metcut	Y. Kim	TiAl	Ti-33.3Al-1.7TiO2
316	Metcut	Y. Kim	TiAl	Ti-33.2Al-6.7TiO2
317	Metcut	Y. Kim	TiAl	Ti-32.9Al-18.3TiO2
318	UES	P. R. Subramanian	Mn	Mn-8.2Al-7.7Nb

Vacuum Arc Melting Operations (Button Melts)

Melt No.	Source Agency	Source Person	Class	Target Composition
319	UES	P. R. Subramanian	Mn	Mn-8.2Al-7.7Nb
320	UES	P. R. Subramanian	Mn	Mn-9.5Nb-7.0Al
321	UES	P. R. Subramanian	Mn	Mn-9.5Nb-7.0Al
322	UES	P. R. Subramanian	Nb	Nb-8.3Al-7.9Mn
323	UES	P. R. Subramanian	Nb	Nb-8.3Al-7.9Mn
324	UES	P. R. Subramanian	Ti	Ti-39.49Nb-20.75Al
325	UES	P. R. Subramanian	Ti	Ti-26.13Nb-21.02Al
326	UES	P. R. Subramanian	Nb	Nb-36.15Ti-24.89Al
327	UES	P. R. Subramanian	Ti	Ti-19.27Nb-11.19Al
328	UES	P. R. Subramanian	Ti	Ti-18.36Nb-10.66Al
329	UES	P. R. Subramanian	Ti	Ti-32.47Nb-18.30Al
330	UES	P. R. Subramanian	TiAl	Al-56.03Ti-20.90Nb
331	UES	P. R. Subramanian	Ti	Ti-30.11Nb-23.31Al
332	UES	P. R. Subramanian	Ti	Ti-18.85Nb-8.22Al
333	UES	P. R. Subramanian	Ti	Ti-27.05Nb-7.86Al
334	UES	P. R. Subramanian	Ti	Ti-33.90Nb-4.92Al
335	UES	P. R. Subramanian	Nb	Nb-28.46Al-9.19Ti
336	UES	P. R. Subramanian	Al	Al-30.86Ti-23.94Nb
337	Metcut	Y. Kim	TiAl	Ti-36.9Al-.8TiO2
338	Metcut	Y. Kim	TiAl	Ti-36.4Al-9.2 TiO2
339	Metcut	Y. Kim	TiAl	Ti-36.8Al-3.3TiO2
340	MLLM	Siamack	Cr	Cr-33.90Hf
341	MLLM	Siamack	Cr	Cr-33.90Hf
342	MLLM	Siamack	Cr	Cr-27.80Zr
343	MLLM	Siamack	Cr	Cr-27.80Zr
344	MLLM	Siamack	Hf	Hf-30.41Cr
345	MLLM	Siamack	Zr	Zr-46.09Cr

Vacuum Arc Melting Operations (Button Melts)

Melt No.	Source Agency	Source Person	Class	Target Composition
346	MLLM	Siamack	Al	Al-34.88Ti-6.40Mn-6.06Cr
347	MLLM	Siamack	Cr	Cr-22Ta
348	MLLM	Siamack	Cr	Cr-22Ta
349	UES	Tom Goff	Nb	Nb-30
350	MLLM	Siamack	Cr	Cr-34Ta
351	MLLM	Siamack	Cr	Cr-34Ta
352	MLLM	Siamack	Cr	Cr-9.0Si
353	MLLM	Siamack	Cr	Cr-9.0Si
354	MLLM	Siamack	Ta	Ta-2Si
355	MLLM	Siamack	Ta	Ta-2Si
356	MLLM	Dennis Dimiduk	TiAl	Ti-37.9Al
357	MLLM	Dennis Dimiduk	TiAl	Ti-36.03Al
358	MLLM	Dennis Dimiduk	TiAl	Ti-34.21Al
359	UES	P. R. Subramanian	NiAl	Ni-25.8Al-18.1Mo
360	UES	P. R. Subramanian	NiAl	Ni-25.8Al-18.1Mo
361	UES	P. R. Subramanian	NiAl	Ni-25.8Al-18.1Mo
362	UES	P. R. Subramanian	NiAl	Ni-25.8Al-18.1Mo
363	UES	P. R. Subramanian	NiAl	Ni-25.8Al-18.1Mo
364	UES	P. R. Subramanian	NiAl	Ni-24.1Al-24.4Mo
365	UES	P. R. Subramanian	NiAl	Ni-24.1Al-24.4Mo
366	MLLM	Siamack	Al	Al-33.77Ti-19.06Cr
367	MLLM	Siamack	Al	Al-36.33Ti-4.73Cr
368	MLLM	Siamack	Al	Al-27.84Ti-19.64Cr
369	MLLM	Siamack	Al	Al-42.26Ti-4.59Cr
370	MLLM	Siamack	Al	Al-40.76Ti-11.80Cr
371	MLLM	Siamack	Al	Al-28.88Ti-12.54Cr
372	MLLM	Siamack	Al	Al-33.41Ti-33.09Mn

Vacuum Arc Melting Operations (Button Melts)

Melt No.	Source Agency	Source Person	Class	Target Composition
373	MLLM	Siamack	Al	Al-36.24Ti-8.29Mn
374	MLLM	Siamack	Al	Al-27.53Ti-34.09Mn
375	MLLM	Siamack	Al	Al-42.15Ti-34.09Mn
376	MLLM	Siamack	TiAl	Ti-38.95Al-20.56Mn
377	MLLM	Siamack	Al	Al-28.68Ti-21.86Mn
378	MLLM	Siamack	Nb	Nb-5.38V-6.26Al
379	MLLM	Siamack	Nb	Nb-5.49V-6.26Al
380	UES	Bob Sweeney	Al	Al-.23
381	UES	P. R. Subramanian	NiAl	Ni-26.7Al-15.3Re
382	UES	P. R. Subramanian	NiAl	Ni-334.3Al
383	UES	P. R. Subramanian	NiAl	Ni-334.3Al
384	UES	P. R. Subramanian	NiAl	Ni-334.3Al
385	UES	P. R. Subramanian	NiAl	Ni-334.3Al
386	UES	Tom Goff	Ti	Ti
387	UES	Bob Sweeney	TiAl	Ti-41.77Al
388	UES	Bob Sweeney	TiAl	Ti-41.77Al
389	UES	Bob Sweeney	TiAl	Ti-41.77Al
390	UES	Bob Sweeney	TiAl	Ti-41.77Al
391	UES	Bob Sweeney	TiAl	Ti-41.77Al
392	UES	Bob Sweeney	TiAl	Ti-41.77Al
393	UES	Bob Sweeney	TiAl	Ti-41.77Al
394	Metcut	Y. Kim	TiAl	Ti-29.00Al
395	Metcut	Y. Kim	TiAl	Ti-27.31Al
396	Metcut	Y. Kim	TiAl	Ti-29.84Al
397	Metcut	Y. Kim	TiAl	Ti-30.70Al
398	Metcut	Y. Kim	TiAl	Ti-31.56Al
399	Metcut	Y. Kim	TiAl	Ti-32.44Al

Vacuum Arc Melting Operations (Button Melts)

Melt No.	Source Agency	Source Person	Class	Target Composition
400	Metcut	Y. Kim	TiAl	Ti-33.32Al
401	Metcut	Y. Kim	TiAl	Ti-34.22Al
402	Metcut	Y. Kim	TiAl	Ti-36.05Al
403	UES	Bob Sweeney	Nb	Nb-15Si
404	UES	Bob Sweeney	Nb	Nb-15Si
405	UES	Bob Sweeney	Nb	Nb-15Si
406	UES	Bob Sweeney	Nb	Nb-15Si
407	UES	Bob Sweeney	Nb	Nb-15Si
408	UES	Bob Sweeney	Nb	Nb-15Si
409	UES	Bob Sweeney	Nb	Nb-15Si
410	UES	Bob Sweeney	Nb	Nb-15Si
411	UES	Bob Sweeney	Nb	Nb-15Si
412	UES	Bob Sweeney	Nb	Nb-15Si
413	UES	Bob Sweeney	Nb	Nb-15Si
414	UES	Bob Sweeney	Nb	Nb-15Si
415	UES	Bob Sweeney	Nb	Nb-15Si
416	UES	Bob Sweeney	Nb	Nb-15Si
417	UES	Bob Sweeney	Nb	Nb-15Si
418	UES	Bob Sweeney	Nb	Nb-15Si
419	UES	Bob Sweeney	TiAl	Ti-21.72Al
420	UES	Bob Sweeney	TiAl	Ti-22.49Al
421	UES	Bob Sweeney	TiAl	Ti-23.27Al
422	MLLM	Siamack	Al	Al-33.77Ti-19.06Cr
423	MLLM	Siamack	Al	Al-27.0Ti-25.0Cr
424	MLLM	Siamack	Al	Al-44.2Ti-6.0Cr
425	MLLM	Siamack	Al	Al-42.08Ti-15.70Cr
426	MLLM	Siamack	Al	Al-33.3Ti-21.7Cr

Vacuum Arc Melting Operations (Button Melts)

Melt No.	Source Agency	Source Person	Class	Target Composition
427	MLLM	Siamack	Mo	Mo-3.0Ni
428	UES	P. R. Subramanian	Mo	Mo-3Ni-3Al
429	UES	P. R. Subramanian	Ni	Ni-35.0Al-.2Mo
430	UES	P. R. Subramanian	Mo	Mo-41.1Ni-18.9Al
431	UES	P. R. Subramanian	Mo	Mo-28.8Ni-13.3Al
432	UES	P. R. Subramanian	Mo	Mo-3Ni-3Al
433	UES	P. R. Subramanian	Ni	Ni-35.0Al-.2Mo
434	UES	P. R. Subramanian	Ni	Ni-40Mo-18.9Al
435	UES	P. R. Subramanian	Mo	Mo-28.8Ni-13.3Al
436	UES	P. R. Subramanian	NiAl	Ni-35Al-.2Mo
437	UES	P. R. Subramanian	Nb	Nb-3.5Si-5.8Ti
438	UES	P. R. Subramanian	Nb	Nb-3.5Si-9.0Ti
439	UES	P. R. Subramanian	Nb	Nb-3.6Si-6.1Ti-1.7Al
440	UES	P. R. Subramanian	Nb	Nb-3.7Si-9.4Ti-1.8Al
441	UES	P. R. Subramanian	Nb	Nb-3.3Si-5.5Mo
442	UES	Vijay Shende	TiAl	Ti-31.78Al-7.10Mn
443	UES	Vijay Shende	TiAl	Ti-34.98Al-2.91Mn
444	UES	Vijay Shende	TiAl	Ti-34.98Al-2.91Mn
445	UES	Vijay Shende	TiAl	Ti-33.45Al-7.17Mn
446	UES	Vijay Shende	TiAl	Ti-36.78Al-2.96Mn
447	UES	Vijay Shende	TiAl	Ti-35.15Al-7.24Mn
448	UES	P. R. Subramanian	NiAl	Ni-24.1Al-23.4Mo
449	UES	P. R. Subramanian	NiAl	Ni-24.1Al-23.4Mo
450	UES	P. R. Subramanian	NiAl	Ni-24.1Al-23.4Mo
451	UES	P. R. Subramanian	NiAl	Ni-24.1Al-23.4Mo
452	MLLN	Paul McQuay	TiAl	Ti-46.57Al-30.11Nb
453	MLLN	Paul McQuay	TiAl	Ti-11.76Al-10.10Nb

Vacuum Arc Melting Operations (Button Melts)

Melt No.	Source Agency	Source Person	Class	Target Composition
454	Metcut	Y. Kim	TiAl	Ti-25.64Al
455	Metcut	Y. Kim	TiAl	Ti-27.31Al
456	Metcut	Y. Kim	TiAl	Ti-29.00Al
457	Metcut	Y. Kim	TiAl	Ti-31.56Al
458	Metcut	Y. Kim	TiAl	Ti-33.22Al
459	Metcut	Y. Kim	TiAl	Ti-33.23Al-2.04Cr
460	Metcut	Y. Kim	TiAl	Ti-33.14Al-5.43Cr
461	UES	P. R. Subramanian	Mo	Mo-41.1Ni-18.9Al
462	UES	P. R. Subramanian	NiAl	Ni-24.1Al-23.4Mo
463	UES	P. R. Subramanian	NiAl	Ni-24.1Al-23.4Mo
464	UES	Madan Mendiratta	Nb	Nb-15Si
465	UES	Madan Mendiratta	Nb	Nb-15Si
466	UES	Madan Mendiratta	Nb	Nb-15Si
467	UES	Madan Mendiratta	Nb	Nb-15Si
468	UES	Madan Mendiratta	Nb	Nb-15Si
469	UES	Madan Mendiratta	Nb	Nb-15Si
470	UES	Madan Mendiratta	Nb	Nb-15Si
471	UES	Madan Mendiratta	Nb	Nb-15Si
472	UES	P. R. Subramanian	Nb	Nb-.12Ma
473	UES	P. R. Subramanian	Nb	Nb-.6Ma
474	UES	P. R. Subramanian	Nb	Nb-.3Ma
475	UES	P. R. Subramanian	Nb	Nb-.6Ma
476	UES	P. R. Subramanian	Nb	Nb-3.3Si-3V
477	UES	P. R. Subramanian	Nb	Nb-3.4Si-6.2V
478	UES	P. R. Subramanian	Nb	Nb-3.4Si-1.6Al
479	UES	P. R. Subramanian	Nb	Nb-3.4Si-.6Al
480	UES	P. R. Subramanian	Mo	Mo-41.1Ni-18.9Al

Vacuum Arc Melting Operations (Button Melts)

Melt No.	Source Agency	Source Person	Class	Target Composition
481	UES	P. R. Subramanian	NiAl	Ni-24.1Al-23.4Mo
482	UES	Madan Mendiratta	Nb	Nb-37.7Cr
483	UES	Madan Mendiratta	Nb	Nb-37.7Cr
484	UES		Al	Al-50Cu
485	UES		Al	Al-50Cu
486	UES	Madan Mendiratta	Cr	Cr-28.2Nb
487	UES	Madan Mendiratta	Cr	Cr-28.2Nb
488	UES	Madan Mendiratta	Cr	Cr-28.2Nb
489	UES	Madan Mendiratta	Cr	Cr-28.2Nb
490	MLLS	Monica Stucke	TiAl	Ti-32.4Al
491	MLLS	Monica Stucke	TiAl	Ti-32.4Al
492	MLLS	Monica Stucke	TiAl	Ti-32.4Al
493	MLLS	Monica Stucke	TiAl	Ti-32.4Al
494	MLLS	Monica Stucke	TiAl	Ti-36Al
495	MLLS	Monica Stucke	TiAl	Ti-36Al
496	MLLS	Monica Stucke	TiAl	Ti-37.9Al
497	MLLS	Monica Stucke	TiAl	Ti-37.9Al
498	MLLS	Monica Stucke	TiAl	Ti-39.8Al
499	MLLS	Monica Stucke	TiAl	Ti-39.8Al
500	MLLS	Monica Stucke	TiAl	Ti-41.8Al
501	MLLS	Monica Stucke	TiAl	Ti-41.8Al
502	UES	P. R. Subramanian	Nb	Nb-6.45Al-34.33Ti
503	UES	P. R. Subramanian	Nb	Nb-4.16Al-45.03Ti
504	UES	P. R. Subramanian	Nb	Nb-8.91Al-33.59Ti
505	UES	P. R. Subramanian	Nb	Nb-32.91Al-2.23Ti
506	UES	P. R. Subramanian	Nb	Nb-32.89-Ti-1.68-Si-1.61Al
507	UES	P. R. Subramanian	Nb	Nb-32.87Ti-3.35Si

Vacuum Arc Melting Operations (Button Melts)

Melt No.	Source Agency	Source Person	Class	Target Composition
508	UES	P. R. Subramanian	Nb	Nb-30.23Ti-8.87Si-2.24Al
509	UES	P. R. Subramanian	Nb	Nb-29.68Ti-9.06Si-3.67Al
510	UES	P. R. Subramanian	Nb	Nb-32.89Ti-1.68Si-1.61Al
511	UES	P. R. Subramanian	Nb	Nb-32.87Ti-3.35Si
512	UES	P. R. Subramanian	Nb	Nb-30.23Ti-8.87Si-2.24Al
513	UES	P. R. Subramanian	Nb	Nb-29.68Ti-9.06Si-3.67Al
514	UES	P. R. Subramanian	Nb	Nb-6.90Si-1.75Al
515	UES	P. R. Subramanian	Nb	Nb-7.09Si-2.87Al
516	UES	P. R. Subramanian	Nb	Nb-3.07Fe
517	MLLM	Dennis Dimiduk	TiAl	Ti-32.5Al-4.8Nb
518	MLLM	Dennis Dimiduk	TiAl	Ti-32.5Al-4.8Nb
519	MLLM	Dennis Dimiduk	TiAl	Ti-33.19Al-2.88Mn
520	MLLM	Dennis Dimiduk	TiAl	Ti-34.08Al-1.89Mn
521	MLLM	Dennis Dimiduk	TiAl	Ti-33.24Al-2.73Cr
522	MLLM	Dennis Dimiduk	TiAl	Ti-34.13Al-2.74Cr
523	MLLM	Dennis Dimiduk	TiAl	Ti-34.10Al-4.10Cr
524	MLLM	Dennis Dimiduk	TiAl	Ti-33.36Al-2.67V
525	MLLM	Dennis Dimiduk	TiAl	Ti-34.15Al-2.69V
526	MLLM	Dennis Dimiduk	TiAl	Ti-33.23Al-4.01V
527	MLLN	Paul McQuay	TiAl	Ti-30.72Al--2.78Mn-4.70Nb
528	Metcut	Y. Kim	TiAl	Ti-32.24Al-2.0V
529	Metcut	Y. Kim	TiAl	Ti-33.22Al-1.44Mn
530	Metcut	Y. Kim	TiAl	Ti-28.56Al-29.30Nb
531	MLLM	Siamack	Cr	Cr-7.47Si
532	MLLM	Siamack	Cr	Cr-7.47Si
533	MLLM	Siamack	Ta	Ta-1.88Si
534	MLLM	Siamack	Ta	Ta-1.88Si

Vacuum Arc Melting Operations (Button Melts)

Melt No.	Source Agency	Source Person	Class	Target Composition
535	MLLM	Siamack	Cr	Cr-29.79Hf
536	MLLM	Siamack	Cr	Cr-7.10Si-6.94Hf
537	MLLM	Siamack	Cr	Cr-25.05Zr
538	UES	P. R. Subramanian	Nb	Nb-4.3Si-35Ti
539	UES	P. R. Subramanian	Nb	Nb-6.7Si-34.2Ti
540	UES	P. R. Subramanian	Nb	Nb-9.2Si-33.5Ti
541	UES	P. R. Subramanian	Nb	Nb-3.1Si-10.1W
542	UES	P. R. Subramanian	Nb	Nb
543	UES	P. R. Subramanian	Nb	Nb-2.6Ni
544	MLLM	Siamack	Cr	Cr-29.79Hf
545	UES	P. R. Subramanian	Nb	Nb-25.4Re
546	UES	P. R. Subramanian	Nb	Nb-19.5 Ma-R545
547	UES	P. R. Subramanian	Nb	Nb-13.0 Ma-R545
548	UES	P. R. Subramanian	Nb	Nb-2.5 Ma-R545
549	UES	P. R. Subramanian	Cr	Cr-25.05Zr
550	UES	P. R. Subramanian	Nb	Nb-5Ru Powder
551	UES	P. R. Subramanian	Nb	Nb-12Ru Powder
552	MLLM	Dennis Dimiduk	TiAl	Ti-34.58Al-2.75Cr-
553	MLLM	Dennis Dimiduk	TiAl	Ti-34.55Al-4.12Cr
554	MLLM	Dennis Dimiduk	TiAl	Ti-34.53Al-2.90Mn
555	MLLM	Dennis Dimiduk	TiAl	Ti-33.85Al-4.81Nb
556	MLLM	Dennis Dimiduk	TiAl	Ti-34.60Al-2.69V
557	UES	Bob Sweeney	NiAl	Ni-50Al
558	UES	P. R. Subramanian	NiAl	Ni-31.5Al
559	UES	P. R. Subramanian	NiAl	Ni-31.5Al
560	UES	P. R. Subramanian	NiAl	Ni-31.5Al
561	UES	P. R. Subramanian	NiAl	Ni-31.5Al

Vacuum Arc Melting Operations (Button Melts)

Melt No.	Source Agency	Source Person	Class	Target Composition
562	UES	P. R. Subramanian	NiAl	Ni-31.5Al
563	UES	P. R. Subramanian	NiAl	Ni-31.5Al
564	UES	P. R. Subramanian	Ni	Ni-40Mo-12.6Al
565	UES	P. R. Subramanian	Ni	Ni-40Mo-12.6Al
566	UES	P. R. Subramanian	Mo	Mo-38.0Ni-12.6Al
567	UES	P. R. Subramanian	Mo	Mo-38.0Ni-12.6Al
568	UES	P. R. Subramanian	Mo	Mo-29.52Ni-12.6Al
569	UES	P. R. Subramanian	Mo	Mo-29.52Ni-12.6Al
570	UES	Madan Mendiratta	Cr	Cr-28.2Nb
571	UES	Madan Mendiratta	Cr	Cr-28.2Nb
572	UES	Madan Mendiratta	Cr	Cr-28.2Nb
573	UES	Madan Mendiratta	Cr	Cr-28.2Nb
574	UES	Madan Mendiratta	Cr	Cr-28.2Nb
575	UES	Madan Mendiratta	Cr	Cr-28.2Nb
576	UES	Madan Mendiratta	Cr	Cr-37.7Cr
577	UES	Madan Mendiratta	Nb	Nb-37.7Cr
578	UES	Madan Mendiratta	Nb	Nb-37.7Cr
579	UES	Madan Mendiratta	Nb	Nb-37.7Cr
580	UES	Madan Mendiratta	Nb	Nb-37.7Cr
581	UES	Madan Mendiratta	Nb	Nb-37.7Cr
582	UES	P. R. Subramanian	Nb	Nb-15.4Si
583	UES	P. R. Subramanian	Nb	Nb-15.4Si
584	UES	P. R. Subramanian	Nb	Nb-15.4Si
585	UES	P. R. Subramanian	Nb	Nb-15.4Si
586	UES	P. R. Subramanian	Nb	Nb-15.4Si
587	UES	P. R. Subramanian	Nb	Nb-15.4Si
588	UES	P. R. Subramanian	Nb	Nb-15.4Si

Vacuum Arc Melting Operations (Button Melts)

Melt No.	Source Agency	Source Person	Class	Target Composition
589	UES	P. R. Subramanian	Nb	Nb-15.4Si
600	UES	P. R. Subramanian	Nb	Nb-15.4Si
601	UES	P. R. Subramanian	Nb	Nb-15.4Si
602	UES	P. R. Subramanian	Nb	Nb-15.4Si
603	UES	P. R. Subramanian	Nb	Nb-15.4Si
604	UES	P. R. Subramanian	Nb	Nb-15.4Si
605	UES	P. R. Subramanian	Nb	Nb-15.4Si
606	UES	P. R. Subramanian	Nb	Nb-15.4Si
607	UES	P. R. Subramanian	Nb	Nb-15.4Si
608	UES	P. R. Subramanian	Nb	Nb-15.4Si
609	UES	P. R. Subramanian	Nb	Nb-15.4Si
610	UES	P. R. Subramanian	Nb	Nb-15.4Si
611	UES	P. R. Subramanian	Nb	Nb-15.4Si
612	UES	P. R. Subramanian	Nb	Nb-15.4Si
613	UES	P. R. Subramanian	Nb	Nb-15.4Si
614	UES	P. R. Subramanian	Nb	Nb-15.4Si
615	UES	P. R. Subramanian	Nb	Nb-15.4Si
616	UES	P. R. Subramanian	Nb	Nb-15.4Si
617	UES	P. R. Subramanian	Nb	Nb-15.4Si
618	UES	P. R. Subramanian	Nb	Nb-15.4Si
619	UES	P. R. Subramanian	Nb	Nb-15.4Si
620	UES	P. R. Subramanian	Nb	Nb-15.4Si
621	UES	P. R. Subramanian	Nb	Nb-15.4Si
622	UES	P. R. Subramanian	Nb	Nb-15.4Si
623	UES	P. R. Subramanian	Nb	Nb-15.4Si
624	MLLM	Dennis Dimiduk	TiAl	Ti-33.7Al-1.49Si
625	MLLM	Dennis Dimiduk	TiAl	Ti-34.02Al-3.014Si

Vacuum Arc Melting Operations (Button Melts)

Melt No.	Source Agency	Source Person	Class	Target Composition
626	MLLM	Dennis Dimiduk	TiAl	Ti-34.76Al-6.16Si
627	MLLM	Dennis Dimiduk	Mo	Mo-36.93Si
628	MLLM	Dennis Dimiduk	TiAl	Ti-34.76Al-6.16Si
629	MLLM	Siamack	Cr	Cr-7.10Si-6.94Hf
630	WSU	Harry Lipsitt	Fe	Fe-2.8Al-11.5Si
631	WSU	Harry Lipsitt	Fe	Fe-5.5Al-8.7Si
632	WSU	Harry Lipsitt	Fe	Fe-5.3Cr-14.5Si
633	UES	P. R. Subramanian	Cr	Cr-9.25Hf
634	UES	P. R. Subramanian	Cr	Cr-3.7Hf
635	UES	P. R. Subramanian	NiAl	Ni-4.25Al
636	UES	P. R. Subramanian	NiAl	Ni-4.25Al
637	UES	Madan Mendiratta	Cr	Cr-.5Hf-28.2Nb
638	UES	Madan Mendiratta	Cr	Cr-.5Hf-28.2Nb
639	UES	P. R. Subramanian	Mo	Mo-28.9Ni
640	UES	P. R. Subramanian	Mo	Mo-29.3Ni
641	UES	P. R. Subramanian	Mo	Mo-30.0Ni
642	UES	P. R. Subramanian	Ni	Ni-28.9Mo
643	UES	P. R. Subramanian	Ni	Ni-29.3Mo
644	UES	P. R. Subramanian	Ni	Ni-30Mo
645	UES	P. R. Subramanian	Nb	Nb-15.4Si
646	UES	P. R. Subramanian	Nb	Nb-15.4Si
647	UES	P. R. Subramanian	Nb	Nb-15.4Si
648	UES	P. R. Subramanian	Nb	Nb-15.4Si
649	UES	P. R. Subramanian	Nb	Nb-15.4Si
650	UES	P. R. Subramanian	Nb	Nb-15.4Si
651	UES	P. R. Subramanian	Nb	Nb-15.4Si
652	UDRI	Sarkar	Al	Alumina Oxide Powder

Vacuum Arc Melting Operations (Button Melts)

Melt No.	Source Agency	Source Person	Class	Target Composition
653	UDRI	Sarkar	Al	Alumina Oxide Powder
654	SRL	Al Jackson	TiAl	Ti-29.5Al-20.7Nb
655	SRL	Al Jackson	TiAl	Ti-29.5Al-20.7Nb
656	SRL	Al Jackson	TiAl	Ti-22.8Al-51.4Nb
657	SRL	Al Jackson	TiAl	Ti-22.8Al-51.4Nb
658	SRL	Al Jackson	TiAl	Ti-32.1Al-54.3Nb
659	SRL	Al Jackson	TiAl	Ti-32.1Al-54.3Nb
660	SRL	Al Jackson	Nb	Nb-37Ti-23Al
661	SRL	Al Jackson	Nb	Nb-37Ti-23Al
662	SRL	Al Jackson	TiAl	Ti-32.2Al-13.2Cr
663	SRL	Al Jackson	TiAl	Ti-32.2Al-13.2Cr
664	SRL	Al Jackson	TiAl	Ti-29.0Al-38.3Cr
665	SRL	Al Jackson	TiAl	Ti-29.0Al-38.3Cr
666	SRL	Al Jackson	TiAl	Ti-41.5Al-41.0Cr
667	SRL	Al Jackson	TiAl	Ti-41.5Al-41.0Cr
668	SRL	Al Jackson	TiAl	Ti-27.6Al-30Cr
669	SRL	Al Jackson	TiAl	Ti-27.6Al-30Cr
670	SRL	Al Jackson	TiAl	Ti-32.4Al-12.7V
671	SRL	Al Jackson	TiAl	Ti-32.4Al-12.7V
672	SRL	Al Jackson	TiAl	Ti-29.5Al-37.3V
673	SRL	Al Jackson	TiAl	Ti-29.5Al-37.3V
674	SRL	Al Jackson	TiAl	Ti-42.2Al-40V
675	SRL	Al Jackson	TiAl	Ti-42.2Al-40V
676	SRL	Al Jackson	TiAl	Ti-27.9Al-27.2V
677	SRL	Al Jackson	TiAl	Ti-27.9Al-27.2V
678	SRL	Al Jackson	TiAl	Ti-32.1Al-13.7Mn
679	SRL	Al Jackson	TiAl	Ti-32.1Al-13.7Mn

Vacuum Arc Melting Operations (Button Melts)

Melt No.	Source Agency	Source Person	Class	Target Composition
680	SRL	Al Jackson	TiAl	Ti-28.6Al-39.2Mn
681	SRL	Al Jackson	TiAl	Ti-28.6Al-39.2Mn
682	SRL	Al Jackson	TiAl	Ti-40.8Al-42MN
683	SRL	Al Jackson	TiAl	Ti-40.8Al-42MN
684	SRL	Al Jackson	TiAl	Ti-27.3Al-28.9Mn
685	SRL	Al Jackson	TiAl	Ti-27.3Al-28.9Mn
686	MLLM	Siamack	Ti	Ti-22.92Mo
687	MLLM	Siamack	Ti	Ti-30.4Mo
688	MLLM	Siamack	Ti	Ti-16.47Mo-28.89Al
689	MLLM	Siamack	Ti	Ti-22.06Mo-27.29Al
690	MLLM	Siamack	Ti	Ti-42.24Mo
691	MLLM	Siamack	Mo	Ti-37.33Mo
692	MLLM	Siamack	Ti	Ti-31.35Mo-25.86Al
693	MLLM	Siamack	Ti	Ti-39.72Mo-24.58Al
694	MLLM	Siamack	Ti	Ti-18.19Mo
695	MLLM	Siamack	Ti	Ti-33.37Mo
696	MLLM	Siamack	Ti	Ti-12.04Mo-33.86Al
697	MLLM	Siamack	Ti	Ti-22.71Mo-31.93Al
698	MLLM	Siamack	Ti	Ti-46.19Mo
699	MLLM	Siamack	Mo	Mo-42.82Ti
700	MLLM	Siamack	Ti	Ti-32.23Mo-30.22Al
701	MLLM	Siamack	Ti	Ti-40.78Mo-26.67Al
702	MLLM	Siamack	Ti	Ti-20.43Mo
703	MLLM	Siamack	Ti	Ti-37.77Mo
704	MLLM	Siamack	Ti	Ti-12.43Mo-39.16Al
705	MLLM	Siamack	Ti	Ti-23.68Mo-37.3Al
706	MLLM	Siamack	Ti	Ti-33.17Mo

Vacuum Arc Melting Operations (Button Melts)

Melt No.	Source Agency	Source Person	Class	Target Composition
707	MLLM	Siamack	Ti	Ti-33.17Mo
708	MLLM	Siamack	Ti	Ti-33.17Mo-34.82Al
709	MLLM	Siamack	Ti	Ti-41.90Mo-33Al
710	MLLM	Dennis Dimiduk	NiAl	Ni-31.49Al
711	MLLM	Dennis Dimiduk	NiAl	Ni-47.08Al-.49Si
712	MLLM	Dennis Dimiduk	NiAl	Ni-31.45Al-.13Si
713	MLLM	Dennis Dimiduk	NiAl	Ni-31.47Al-.07Si
714	MLLM	Dennis Dimiduk	NiAl	Ni-31.48Al-.03Si
715	MLLM	Dennis Dimiduk	NiAl	Ni-46.71Al-1.67Mo
716	MLLM	Dennis Dimiduk	NiAl	Ni-47.02Al-.67Mo
717	MLLM	Dennis Dimiduk	NiAl	Ni-31.42Al-.22Mo
718	MLLM	Dennis Dimiduk	NiAl	Ni-31.46Al-0.11Mo
719	MLLM	Dennis Dimiduk	NiAl	Ni-31.24Al-.81Ga
720	MLLM	Dennis Dimiduk	NiAl	Ni-31.39Al-.33Ga
721	MLLM	Dennis Dimiduk	NiAl	Ni-31.44Al-.16Ga
722	MLLM	Dennis Dimiduk	NiAl	Ni-31.46Al-.08Ga
723	MLLM	Dennis Dimiduk	NiAl	Ni-31.39Al-.33Ga
724	MLLM	Dennis Dimiduk	NiAl	Ni-31.36Al-.41Y
725	MLLM	Dennis Dimiduk	NiAl	Ni-31.43Al-.21Y
726	MLLM	Dennis Dimiduk	NiAl	Ni-31.46Al-.10Y
727	MLLM	Dennis Dimiduk	NiAl	Ni-46.99Al-34Mo-.62Y
728	MLLM	Dennis Dimiduk	NiAl	Ni-46.90Al-.33Mo-.12Ga
729	MLLM	Dennis Dimiduk	NiAl	Ni-47.09Al-.34Mo-.12Ga
730	MLLM	Dennis Dimiduk	NiAl	Ni-47.11Al-.10Si-.31Y
731	MLLM	Dennis Dimiduk	NiAl	Ni-47.12Al-.05Si-.31Y
732	MLLM	Dennis Dimiduk	NiAl	Ni-31.49Al
733	MLLM	Dennis Dimiduk	NiAl	Ni-31.29Al-.65Fe

Vacuum Arc Melting Operations (Button Melts)

Melt No.	Source Agency	Source Person	Class	Target Composition
734	MLLM	Dennis Dimiduk	NiAl	Ni-31.41Al-.26Fe
735	MLLM	Dennis Dimiduk	NiAl	Ni-31.45Al-.13Fe
736	MLLM	Dennis Dimiduk	NiAl	Ni-31.47Al-.07Fe
737	MLLM	Dennis Dimiduk	NiAl	Ni-31.29Al-.64Mn
738	MLLM	Dennis Dimiduk	NiAl	Ni-31.41Al-.26Mn
739	MLLM	Dennis Dimiduk	NiAl	Ni-31.45Al-.13Mn
740	MLLM	Dennis Dimiduk	NiAl	Ni-31.47Al-.06Mn
741	MLLM	Dennis Dimiduk	NiAl	Ni-30.82Al-2.14Re
742	MLLM	Dennis Dimiduk	NiAl	Ni-31.22Al-.86Re
743	MLLM	Dennis Dimiduk	NiAl	Ni-31.35Al-.43Re
744	MLLM	Dennis Dimiduk	NiAl	Ni-31.42Al-.22Re
745	MLLM	Dennis Dimiduk	NiAl	Ni-31.29Al-.65Ce
746	MLLM	Dennis Dimiduk	NiAl	Ni-31.39Al-.33Ce
747	MLLM	Dennis Dimiduk	NiAl	Ni-31.44Al-.16Ce
748	MLLM	Dennis Dimiduk	NiAl	Ni-31.29Al-.65La
749	MLLM	Dennis Dimiduk	NiAl	Ni-31.39Al-.32La
750	MLLM	Dennis Dimiduk	NiAl	Ni-31.44Al-.16lA
751	MLLM	Dennis Dimiduk	NiAl	Ni-31.25Al-.78E
752	MLLM	Dennis Dimiduk	NiAl	Ni-31.37Al-.39Er
753	MLLM	Dennis Dimiduk	NiAl	Ni-43Al-.19Er
754	MLLM	Dennis Dimiduk	Ni	Ni-28.1Ti
755	UES	P. R. Subramanian	Si	Si-38.79Al
756	UES	P. R. Subramanian	Al	Al-34.68Si
757	UES	P.R. Subramanian	Nb	Nb-29.1Ti
758	UES	P. R. Subramanian	Nb	Nb-34.04Ti
759	UES	P. R. Subramanian	Si	Si-32.4Al
760	UES	P. R. Subramanian	Si	Si-48.8Al

Vacuum Arc Melting Operations (Button Melts)

Melt No.	Source Agency	Source Person	Class	Target Composition
761	UES	Bob Sweeney	Nb	Nb-37.7Cr
762	UES	Bob Sweeney	Nb	Nb-37.7Cr
763	UES	Bob Sweeney	Nb	Nb-37.7Cr
764	UES	Bob Sweeney	Nb	Nb-37.7Cr
765	UES	P. R. Subramanian	NiAl	Ni-19.46Al
766	UES	P. R. Subramanian	NiAl	Ni-31.5Al
767	UES	P. R. Subramanian	NiAl	Ni-40Mo-19.46Al
768	UES	P. R. Subramanian	NiAl	Ni-37.5Mo-31.5Al
769	UES	Vijay Shende	TiAl	Ti-37.9Al+
770	UES	P. R. Subramanian	Mo	Mo-.25Ti
771	UES	P. R. Subramanian	Mo	Mo-.25Ti
772	UES	P. R. Subramanian	Mo	Mo-.25Ti
773	UES	P. R. Subramanian	Mo	Mo-.25Ti
774	UES	P. R. Subramanian	NiAl	Ni-32.13Al
775	UES	P. R. Subramanian	NiAl	Ni-32.13Al
776	UES	P. R. Subramanian	Mo	Mo-4.61Ti
777	UES	P. R. Subramanian	Mo	Mo-4.61Ti
778	MLLM	Jim Morgan	TiAl	Ti-28.25Al-21.60Nb
779	MLLM	Jim Morgan	TiAl	Ti-29.49Al-13.50Nb
780	MLLM	Jim Morgan	TiAl	Ti-26.85Al-30.80Nb
781	MLLM	Jim Morgan	TiAl	Ti-31.41Al-7.9V
782	MLLM	Jim Morgan	TiAl	Ti-31.31Al-13.10V
783	MLLM	Jim Morgan	TiAl	Ti-31.19Al-19.6V
784	MLLM	Dan Evans	Mo	Mo-36.24Si
785	MLLM	Dan Evans	Mo	Mo-36.24Si
786	MLLM	Dan Evans	Mo	Mo-36.24Si
787	MLLM	Dan Evans	Mo	Mo-36.24Si

Vacuum Arc Melting Operations (Button Melts)

Melt No.	Source Agency	Source Person	Class	Target Composition
788	MLLM	Dan Evans	Mo	Mo-36.24Si
789	MLLM	Dan Evans	NiAl	Ni-31.4Al-1.11Mo
790	UES	Vijay Shende	TiAl	Ti-32.75Al
	UES	Vijay Shende	TiAl	Ti-30.13Al
	UES	Vijay Shende	Nb	Nb-9.62Al
	UES	Vijay Shende	Nb	Nb-7.39Al
	UES	Vijay Shende	Nb	Nb-3.47Al
	UES	Vijay Shende	Nb	Nb-5.34Al
	UES	Vijay Shende	Nb	Nb-9.63Al
	UES	Vijay Shende	Nb	Nb-5.34Al
	UES	Vijay Shende	Nb	Nb-7.39Al
	UES	Vijay Shende	Nb	Nb-3.43Al
791	UES	P. R. Subramanian	Ni	Ni-31.93Al
792	UES	P. R. Subramanian	Ni	Ni-31.93Al
793	UES	P. R. Subramanian	Mo	Mo-4.05Ti
794	UES	P. R. Subramanian	Mo	Mo-29.8Ni-13.98Al-3.1Ti
795	UES	P. R. Subramanian	NiAl	Ni-31.93Al
796	UES	P. R. Subramanian	Mo	Mo-12.3Ti
797	UES	P. R. Subramanian	NiAl	Ni-31.93Al
798	UES	P. R. Subramanian	Ni	Ni-31.93Al
799	UES	P. R. Subramanian	Ni	Ni-39.84Mo-19.2Al
800	UES	P. R. Subramanian	Ni	Ni-39.84Mo-19.2Al
801	UES	P. R. Subramanian	Ni	Ni-31.93Al
802	UES	P. R. Subramanian	Ni	Ni-31.93Al
803	UES	P. R. Subramanian	Ni	Ni-39.84Mo-19.2Al
804	UES	P. R. Subramanian	Ni	Ni-39.84Mo-19.2Al
805	Metcut	Y. Kim	TiAl	Ti-33.38Al-.22Si
806	Metcut	Y. Kim	TiAl	Ti-33.45Al-.52Si
807	Metcut	Y. Kim	TiAl	Ti-33.59Al-1.11Si
808	Metcut	Y. Kim	TiAl	Ti-33.42Al-.09B
809	Metcut	Y. Kim	TiAl	Ti-33.56Al-.20B
810	Metcut	Y. Kim	TiAl	Ti-33.82Al-.44B

Vacuum Arc Melting Operations (Button Melts)

Melt No.	Source Agency	Source Person	Class	Target Composition
811	UES	P. R. Subramanian	Nb	Nb-45.06Mo-11.31Si
812	UES	P. R. Subramanian	Nb	Nb-64.33Mo-8.97Ai
813	UES	P. R. Subramanian	Nb	Nb-50Mo-37.12Si
814	UES	P. R. Subramanian	Nb	Nb-40.02Mo-33.55Si
815	UES	P. R. Subramanian	Nb	Nb-59.32Mo-37.01Si
816	UES	P. R. Subramanian	Nb	Nb-29.42Ti-7.01Zr-6.47Si
817	UES	P. R. Subramanian	Nb	Nb-27.15Ti-13.79Zr-6.37Si
818	Metcut	Y. Kim	TiAl	Ti-32.44Al
819	Metcut	Y. Kim	TiAl	Ti-33.33Al
820	Metcut	Y. Kim	TiAl	Ti-34.22Al
821	Metcut	Y. Kim	TiAl	Ti-32.69Al-1.12Si
822	Metcut	Y. Kim	TiAl	Ti-33.68Al-1.49Si
823	Metcut	Y. Kim	TiAl	Ti-34.59Al-1.49Si
824	Metcut	Y. Kim	TiAl	Ti-34.85Al-.74B
825	Metcut	Y. Kim	TiAl	Ti-35.45Al-.43B
826	UES	P. R. Subramanian	NiAl	Ni-31.5Al
827	UES	P. R. Subramanian	NiAl	Ni-31.5Al
828	UES	P. R. Subramanian	NiAl	Ni-31.5Al
829	UES	P. R. Subramanian	NiAl	Ni-31.5Al
830	UES	P. R. Subramanian	NiAl	Ni-31.5Al
831	UES	P. R. Subramanian	NiAl	Ni-31.5Al
832	UES	P. R. Subramanian	Nb	Nb-26.7Ti-15.1Ru-6.3Si
833	MLLS	Monica Stucke	TiAl	Ti-38.85Al
834	MLLS	Monica Stucke	TiAl	Ti-40.75Al
835	MLLS	Monica Stucke	TiAl	Ti-42.25Al
836	Metcut	Gopal Das	Ti	Ti-17Si
837	Metcut	Gopal Das	Ti	Ti-6Al-17.5Si-36Nb

Vacuum Arc Melting Operations (Button Melts)

Melt No.	Source Agency	Source Person	Class	Target Composition
838	Metcut	Y. Kim	TiAl	Ti-32.93Al-1.83Ce
839	Metcut	Y. Kim	TiAl	Ti-32.54Al-3.59Ce
840	Metcut	Y. Kim	TiAl	Ti-32.81Al-2.16Er
841	Metcut	Y. Kim	TiAl	Ti-32.31Al-4.26Er
842	Metcut	Krishnamurthy	TiAl	Ti-12.5Al-43.0Nb
843	Metcut	Krishnamurthy	TiAl	Ti-12.5Al-43.1Nb-.1Si
844	Metcut	Krishnamurthy	TiAl	Ti-12.5Al-43.1Nb-.2Si
845	Metcut	Krishnamurthy	TiAl	Ti-12.6Al-43.2Nb-.5Si
846	Metcut	Krishnamurthy	TiAl	Ti-12.5Al-43.1Nb-.2Si
847	Metcut	Krishnamurthy	TiAl	Ti-12.6Al-43.2Nb-.5Si
848	Metcut	Y. Kim	TiAl	Ti-33.15Al-1.16Y
849	Metcut	Y. Kim	TiAl	Ti-32.97Al-2.31Y
850	Metcut	Y. Kim	TiAl	Ti-33.35Al-1.18Sc
851	Metcut	Y. Kim	TiAl	Ti-33.40Al-3.55Sc
852	UES	Bob Sweeney	W	Tungsten molydenum aluminide
853	UES	Bob Sweeney	W	Tungsten in copper cylinder
854	UES	Bob Sweeney	Al	Aluminide in copper cylinder
855	UES	Bob Sweeney	Mo	Mo in copper cylinder
856	UES	Bob Sweeney	Ti	Ti-26.0Si
857	UES	Bob Sweeney	Ti	Ti-26.0Si
858	UES	Bob Sweeney	Ti	Ti-26.0Si
859	UES	Bob Sweeney	Ti	Ti-26.0Si
860	MLLM	Andy Thom	Cr	Cr-24.5Si
861	MLLM	Andy Thom	Cr	Cr-24.5Si
862	MLLM	Andy Thom	Cr	Cr-24.5Si
863	MLLM	Andy Thom	Cr	Cr-24.5Si
864	MLLM	Andy Thom	Mo	Mo-14.94Si

Vacuum Arc Melting Operations (Button Melts)

Melt No.	Source Agency	Source Person	Class	Target Composition
865	MLLM	Andy Thom	Mo	Mo-14.94Si
866	MLLM	Andy ThoM	Mo	Mo-14.94Si
867	MLLM	Andy Thom	Mo	Mo-14.94Si
868	MLLM	Andy Thom	Mo	Mo-36.93Si
869	MLLM	Andy Thom	Mo	Mo-36.93Si
870	MLLM	Andy Thom	Mo	Mo-36.93Si
871	MLLM	Andy Thom	Mo	Mo-36.93Si
872	MLLM	Andy Thom	Nb	Nb-37.68Si
873	MLLM	Andy Thom	Nb	Nb-37.68Si
874	MLLM	Andy Thom	Nb	Nb-37.68Si
875	MLLM	Andy Thom	Nb	Nb-47.1Si
876	Metcut	Y. Kim	TiAl	Ti-29.84Al
877	Metcut	Y. Kim	TiAl	Ti-29.84Al
878	Metcut	Y. Kim	TiAl	Ti-33.32Al
879	Metcut	Y. Kim	TiAl	Ti-33.32Al
880	MLLM	Andy Thom	Ti	Ti-26.0Si
881	MLLM	Andy Thom	Ti	Ti-26.0Si
882	MLLM	Andy Thom	Ti	Ti-26.0Si
883	MLLM	Andy Thom	Ti	Ti-26.0Si
884	MLLM	Andy Thom	Ti	Ti-26.0Si
885	MLLM	Andy Thom	Ti	Ti-26.0Si
886	MLLM	Andy Thom	Ti	Ti-26.0Si
887	MLLM	Andy Thom	Ti	Ti-26.0Si
888	Metcut	Y. Kim	NiAl	Ni-23.34Al-16.88Mo-8.99W
889	Metcut	Y. Kim	NiAl	Ni-21.22Al-16.82W-15.79Mo
890	Metcut	Y. Kim	Mo	Mo-42.05W
891	Metcut	Y. Kim	Mo	Mo-22.48W

Vacuum Arc Melting Operations (Button Melts)

Melt No.	Source Agency	Source Person	Class	Target Composition
892	Metcut	Y. Kim	NiAl	Ni-31.5Al
893	Metcut	Y. Kim	NiAl	Ni-31.5Al
894	Metcut	Y. Kim	NiAl	Ni-31.5Al
895	Metcut	Y. Kim	Mo	Mo-21.7Al
896	Metcut	Y. Kim	NiAl	Ni-29.93Al
897	Metcut	Y. Kim	Al	Al-26.4Mo
898	Metcut	Y. Kim	NiAl	Ni-24.23Al-18.03Mo-.05Ti
899	Metcut	Y. Kim	Ti	Ti-26.03Si
900	Metcut	Y. Kim	Mo	Mo-12.50Ti
901	Metcut	Y. Kim	NiAl	Ni-31.48Al
902	Metcut	Y. Kim	NiAl	Ni-24.23Al-18.03Mo-5.0Ti
903	Metcut	Y. Kim	TiAl	Ti-33.60Al-.14B
904	Metcut	Y. Kim	TiAl	Ti-33.49Al-.14B
905	Metcut	Y. Kim	TiAl	Ti-34.39Al-.14B
906	Metcut	Y. Kim	TiAl	Ti-33.66Al-.14B
907	Metcut	Y. Kim	TiAl	Ti-32.49Al-.22Si
908	Metcut	Y. Kim	TiAl	Ti-34.28Al-.22Si
909	Metcut	Y. Kim	TiAl	Ti-33.01Al-1.09Ce
910	Metcut	Y. Kim	TiAl	Ti-33.02Al-1.3Er
911	Metcut	Y. Kim	TiAl	Ti-33.22Al-.7Y
912	Metcut	Y. Kim	TiAl	Ti-32.60Al-.14B
913	Metcut	Y. Kim	TiAl	Ti-33.49Al-.14B
914	Metcut	Y. Kim	TiAl	Ti-34.39Al-.14B
915	Metcut	Y. Kim	TiAl	Ti-33.60Al-.29B
916	Metcut	Y. Kim	TiAl	Ti-33.21Al-.55Ce
917	Metcut	Y. Kim	TiAl	Ti-33.17Al-.66Er
918	Metcut	Y. Kim	TiAl	Ti-33.27Al-.35Y

Vacuum Arc Melting Operations (Button Melts)

Melt No.	Source Agency	Source Person	Class	Target Composition
919	UES	Tom Goff	Ti	Test
920	UES	P. R. Subramanian	Nb	Nb-34.02Ti
921	UES	P. R. Subramanian	Si	Si-29.35Al
922	UES	P. R. Subramanian	Nb	Nb-26.93Ti-15.79Si-5.0Al
923	UES	P. R. Subramanian	Nb	Nb-34.03Ti
924	UES	P. R. Subramanian	Si	Si-25.66Al
925	UES	P. R. Subramanian	Nb	Nb-26.93Ti-15.79Si-5.05Al
926	UES	P. R. Subramanian	Nb	Nb-34.02Ti
927	UES	P. R. Subramanian	Si	Si-33.52Al
928	UES	P. R. Subramanian	Nb	Nb-25.73Ti-16.46Si-7.90Al-
929	UES	P. R. Subramanian	Nb	Nb-37.1Ti
930	UES	P. R. Subramanian	Al	Al-4.86Si
931	UES	P. R. Subramanian	Nb	Nb-34.41Ti-.37Si-6.88Al
932	UES	P. R. Subramanian	Si	Si-25.76Al
933	UES	P. R. Subramanian	Nb	Nb-27Ti-20.57Zr
934	UES	P. R. Subramanian	Nb	Nb-21.60Ti-16.45Zr-15.19Si
935	UES	P. R. Subramanian	Nb	Nb-26.26Ti-31.03Ru-.11Si
936	UES	P. R. Subramanian	TiAl	Ti-16.88Al-4.89Si
937	UES	P. R. Subramanian	Mo	Mo-49.2Nb
938	UES	P. R. Subramanian	Mo	Mo-37.33Nb-19.18Ti-3.74Al-1.20Si
939	UES	Madan Mendiratta	Fe	Fe-14.3Si
940	Metcut	Y. Kim	TiAl	Ti-32.37Al-2.71Cr
941	Metcut	Y. Kim	TiAl	Ti-33.26Al-2.73Cr
942	Metcut	Y. Kim	TiAl	Ti-34.15Al-2.74Cr
943	Metcut	Y. Kim	TiAl	Ti-31.63Al-2.65Cr-4.73Nb
944	Metcut	Y. Kim	TiAl	Ti-30.92Al-2.59Cr-9.25Nb
945	Metcut	Y. Kim	TiAl	Ti-30.24Al-2.53Cr-13.57Nb

Vacuum Arc Melting Operations (Button Melts)

Melt No.	Source Agency	Source Person	Class	Target Composition
946	Metcut	Y. Kim	TiAl	Ti-28.97Al-2.43Cr-21.67Nb
947	Metcut	Y. Kim	TiAl	Ti-32.49Al-2.66Cr-4.76Nb
948	Metcut	Y. Kim	TiAl	Ti-31.76Al-2.60Cr-1.30Nb
949	Metcut	Y. Kim	TiAl	Ti-31.06Al-2.55Cr-27.28Nb
950	Metcut	Y. Kim	TiAl	Ti-29.75Al-2.44Cr-21.78Nb
951	Metcut	Y. Kim	TiAl	Ti-33.36Al-2.68Cr-4.78Nb
952	Metcut	Y. Kim	TiAl	Ti-32.60Al-2.62Cr-9.35Nb
953	Metcut	Y. Kim	TiAl	Ti-31.88Al-2.56Cr-13.72Nb
954	Metcut	Y. Kim	TiAl	Ti-29.75Al-2.44Cr-21.78Nb
955	UES	P. R. Subramanian	Nb	Nb-34.02Ti
956	UES	P. R. Subramanian	Nb	Nb-34.02Ti
957	UES	P. R. Subramanian	Si	Si-29.35Al
958	UES	P. R. Subramanian	Si	Si-25.66Al
959	UES	P. R. Subramanian	Nb	Nb-28.06Ti-12.66Si-4.86Al
960	UES	P. R. Subramanian	Nb	Nb-26.93Ti-15.79Si-5.05Al
961	UES	P. R. Subramanian	Nb	Nb-34.02Ti
962	UES	P. R. Subramanian	Nb	Nb-37.1Ti
963	UES	P. R. Subramanian	Si	Si-33.52Al
964	UES	P. R. Subramanian	Al	Al-4.86Si
965	UES	P. R. Subramanian	Nb	Nb-25.73Ti-16.46Si-7.9Al
966	UES	P. R. Subramanian	Nb	Nb-34.41Ti-6.88Al-.37Si
967	UES	P. R. Subramanian	Si	Si-25.76Al
968	UES	P. R. Subramanian	Nb	Nb-27Ti-20.57Zr
969	UES	P. R. Subramanian	Nb	Nb-21.60Ti-16.45Zr-15.19Si-4.87Ru
970	UES	P. R. Subramanian	Nb	Nb-26.26Ti-Ti-31.03Ru-.11Si
971	UES	P. R. Subramanian	Mo	Mo-39.27Nb-20.87Ti
972	UES	P. R. Subramanian	Al	Al-22.47Si

Vacuum Arc Melting Operations (Button Melts)

Melt No.	Source Agency	Source Person	Class	Target Composition
973	UES	P. R. Subramanian	Nb	Nb-38.55Mo-19.18Ti-3.74Al-1.2Si
974	UES	P. R. Subramanian	Nb	Nb-3.98Al
975	UES	P. R. Subramanian	Nb	Nb-5.61Al
976	UES	P. R. Subramanian	Nb	Nb-4.21Al-Ti-5.97
977	UES	P. R. Subramanian	Nb	Nb-4.46Al-Ti-2.66
978	UES	P. R. Subramanian	Nb	Nb-5.94Al-6.20Ti
979	UES	P. R. Subramanian	Nb	Nb-6.12Al-9.58Ti
980	UES	P. R. Subramanian	Nb	Nb-6.31Al-13.73Ti
981	UES	P. R. Subramanian	Nb	Nb-6.73Al-21.06Ti
3,252	MLLM	Dan Miracle	Nb	Nb-.08Si
3,253	MLLM	Dan Miracle	Nb	Nb-.16Si
3,254	MLLM	Dan Miracle	Nb	Nb-.24Si
3,255	MLLM	Dan Miracle	Nb	Nb-.32Si
3,256	MLLM	Dan Miracle	Nb	Nb-.4Si
3,257	MLLM	Dan Miracle	Nb	Nb-.48Si
3,258	MLLM	Dan Miracle	Nb	Nb-15.4Si
3,259	MLLM	Y. Kim	Ti	Ti-33Al
3,260	MLLM	Y. Kim	Ti	Ti-33Al-4V
3,261	MLLM	Dan Miracle	Cr	Cr-6.9Si
3,262	MLLM	Dan Miracle	Cr	Cr-17.2Si
3,263	MLLM	Dan Miracle	Cr	Cr-28.1Si
3,264	MLLM	Dan Miracle	Cr	Cr-38.1Si
3,265	MLLM	Y. Kim	Ti	Ti-33Al-7.99V
3,266	MLLM	Y. Kim	Ti	Ti-33.05Al-11.95V
3,267	MLLM	Y. Kim	Ti	Ti-33.18Al-4.08Cr
3,268	MLLM	Joe Newkirk	Cr	Cr-7Si
3,269	MLLM	Joe Newkirk	Cr	Cr-9Si

Vacuum Arc Melting Operations (Button Melts)

Melt No.	Source Agency	Source Person	Class	Target Composition
3,270	MLLM	Y. Kim	Ti	Ti-33.07Al-8.13Cr
3,271	MLLM	Y. Kim	Ti	Ti-82.8Al-19.9V
3,272	MLLM	Y. Kim	Ti	Ti-33.16Al-2.87Mn
3,273	MLLM	Y. Kim	Ti	Ti-33.04Al-5.73Mn
3,274	MLLM	Y. Kim	Ti	Ti-33.07Al-8.13Cr
3,275	MLLM	Y. Kim	Ti	Ti-32.51Al-4.7Nb
3,276	MLLM	Y. Kim	Ti	Ti-31.78Al-7.32Nb
3,277	MLLM	Y. Kim	Ti	Ti-31.08Al-13.67Nb
3,278	MLLM	Y. Kim	Ti	Ti-29.77Al-21.82Nb
3,279	MLLM	Vijay Shende	Ti	Ti-37.9Al
3,280	MLLM	Vijay Shende	Ti	Ti-34.21Al
3,281	MLLM	Vijay Shende	Ti	Ti-34.21Al
3,282	MLLS	Y. Kim	Ti	Ti-12.5TiO2
3,283	MLLS	Y. Kim	Ti	Ti-25.0TiO2
3,284	MLLM	Krishnamurthy	Ti	Ti-38Al
3,285	MLLM	Krishnamurthy	Ti	Ti-62-38Al
3,286	MLLM	Krishnamurthy	Ti	Ti-34.2Al
3,287	MLLM	Krishnamurthy	Ti	Ti-38.0Al
3,288	MLLM	Krishnamurthy	Ti	Ti-34.2Al-2.7V
3,289	MLLM	Krishnamurthy	Ti	Ti-14Al-21Nb
3,290	MLLM	Krishnamurthy	Ti	Ti-12.7Al-30.9Nb-1.9Mo
3,291	MLLM	Krishnamurthy	Ti	Ti-14.2Al-191.4Nb-3.2V-2.0Mo
3,292	UES	Tom Goff	Ti	Ti-CP
3,293	UES	P. R. Subramanian	Nb	Nb-3.1Si-10.1W
3,294	UES	Tai-il Mah	Y	Yttrium Oxide
3,295	MLLM	Dennis Dimiduk	Al	Al-21Rh
3,296	UES	P. R. Subramanian	Ni	Ni-44.1Al-.4Mo

Vacuum Arc Melting Operations (Button Melts)

Melt No.	Source Agency	Source Person	Class	Target Composition
3,297	MLLS	Siamack	Ti	Ti-22.71Mo-31.93Al
3,298	MLLS	Siamack	Ti	Ti-23.68Mo-37.30Al
3,299	UES	Bob Sweeney	Cr	Cr-28.2Nb
3,300	UES	Bob Sweeney	Cr	Cr-28.2Nb
3,301	UES	Bob Sweeney	Cr	Cr-28.2Nb
3,302	UES	Bob Sweeney	Cr	Cr-28.2Nb
3,303	UES	Bob Sweeney	Cr	Cr-28.2Nb
3,304	UES	Bob Sweeney	Cr	Cr-28.2Nb
3,305	UES	Bob Sweeney	Cr	Cr-28.2Nb
3,306	UES	Bob Sweeney	Cr	Cr-28.2Nb

APPENDIX D: LIST OF VACUUM INDUCTION MELTING OPERATIONS

Vacuum Induction Melting Operations

Retech Melt No.	Source Agency	Charge Material	Charge Weight kg (lb)
179	UES	CP-Al	3.2 (7)
180	UES	CP-Al	1.4 (3)
181	UES	CP-Al	1.4 (3)
182	UES	CP-Al	1.4 (3)
183	UES	1020 Steel	0 (0)
184	UES	CP-Al	1.4 (3)
185	UES	CP-Al	1.4 (3)
186	UES	CP-Al	3.3 (7.2)
187	UES	1020 Steel Bar	4.5 (10)
188	UES	CP-Al	3.3 (7.2)
189	UES	CP-Al	3.2 (7)
190	Ohio State Univ.	Al-6.0W/o-Cu	3.4 (7.5)
191	UES	1020 Steel	0 (0)
192	Ohio State Univ.	CP-Al w/Copper	3.4 (7.5)
193	UES	CP-Al	2.9 (6.4)
194	Ohio State Univ.	Al+2.5W/o-Cu	3.2 (7)
195	Ohio State Univ.	Al+2.5W/o Cu	3.2 (7)
196	UES	CP-Al	3.2 (7)
197	UES	CP-Al	3.2 (7)
198	UES	CP-Al	1.5 (3.2)
199	UES	CP-Al	3.2 (7)
200	UES	CP-Al	1 (2.3)
201	UES	Al-4.5% Cu	1.6 (3.5)
202	UES	CP-Al-4.5% Cu	1.6 (3.5)
203	UES	A357 (Al Alloy)	3.3 (7.3)
204	UES	Pure Al-4.5% Cu	1.9 (4.1)
205	UES	CP-Al	1.7 (3.7)

Vacuum Induction Melting Operations

Retech Melt No.	Source Agency	Charge Material	Charge Weight kg (lb)
207	UES	Pure Al-4.5% Cu	1.7 (3.7)
208	UES	713C	4.8 (10.5)
209	UES	713C	1.8 (4)
210	UES	713C	2 (4.4)
211	UES	713C	3.6 (8)
212	UES	713C	3.6 (8)
213	UES	713C	3.6 (8)
214	UES	713C	3.7 (8.1)
215	UES	718	3.6 (8)
216	UES	718	3.6 (8)
217	UES	CP-Al	2.8 (6.1)

APPENDIX E: LIST OF FORGING OPERATIONS

Forging Operations

Forging No.	Source	Ram Speed cm/s (in/s)	Die Temp C (F)	Billet Temp C (F)	Billet Composition
6868	UES	Max.	899 (1650)	871 (1600)	Ti-6Al-4V
6869	UES	Max.	899 (1650)	871 (1600)	Ti-6Al-4V
6870	UES	2.54 (1)	871 (1600)	871 (1600)	Ti-6Al-4V
6871	UES	2.54 (1)	871 (1600)	871 (1600)	Ti-6Al-4V
6872	UES	2.54 (1)	760 (1400)	807 (1485)	Ti-6Al-4V
6873	UES	2.54 (1)	816 (1500)	816 (1500)	Ti-6Al-4V
6874	UES	2.54 (1)	816 (1500)	816 (1500)	Ti-6Al-4V
6875	UES	2.54 (1)	316 (600)	316 (600)	Al-7075
6876	UES	2.54 (1)	316 (600)	316 (600)	Al-7075
6877	UES	2.54 (1)	316 (600)	316 (600)	Al-7075
6878	UES	2.54 (1)	316 (600)	316 (600)	Al-7075
6879	UES	2.54 (1)	316 (600)	316 (600)	Al-7075
6880	UES	2.54 (1)	316 (600)	316 (600)	Al-7075
6881	UES	2.54 (1)	316 (600)	316 (600)	Al-7075
6882	UES	2.54 (1)	316 (600)	316 (600)	Al-7075
6883	UES	2.54 (1)	816 (1500)	816 (1500)	Ti-6Al-4V
6884	UES	2.54 (1)	816 (1500)	816 (1500)	Ti-6Al-4V
6885	UES	2.54 (1)	816 (1500)	816 (1500)	Ti-6Al-4V
6886	UES	2.54 (1)	816 (1500)	816 (1500)	Ti-6Al-4V
6887	UES	2.54 (1)	816 (1500)	816 (1500)	Ti-6Al-4V
6888	UES	7.62 (3)	871 (1600)	871 (1600)	Al-15Nb-41Cr
6889	UES	76.2 (30)	871 (1600)	1204 (2200)	Ti-48Al
6890	UES	76.2 (30)	871 (1600)	1204 (2200)	NiAl-9Mo
6891	UES	76.2 (30)	871 (1600)	1204 (2200)	NiAl-9Mo
6892	UES	76.2 (30)	871 (1600)	1204 (2200)	NiAl-9Mo
6893	UES	76.2 (30)	871 (1600)	1204 (2200)	Ti-52Al
6894	Metcut	76.2 (30)	871 (1600)	1232 (2250)	Ti-Al-Nb

Forging Operations

Forging No.	Source	Ram Speed cm/s (in/s)	Die Temp C (F)	Billet Temp C (F)	Billet Composition
6895	Metcut	76.2 (30)	871 (1600)	1232 (2250)	TiAl-V
6896	Metcut	76.2 (30)	871 (1600)	1232 (2250)	TiAl-V
6897	Metcut	12.7 (5)	871 (1600)	1232 (2250)	TiAl-Cr
6898	Metcut	2.54 (1)	871 (1600)	1232 (2250)	TiAl-Mn
6899	Metcut	1.27 (.5)	871 (1600)	1204 (2200)	TiAl-Nb
6900	Metcut	76.2 (30)	871 (1600)	1232 (2250)	TiAl
6901	Metcut	76.2 (30)	871 (1600)	1232 (2250)	TiAl
6902	Metcut	76.2 (30)	871 (1600)	1232 (2250)	TiAl
6903	Metcut	76.2 (30)	871 (1600)	1232 (2250)	TiAl
6904	Metcut	76.2 (30)	871 (1600)	1232 (2250)	TiAl
6905	Metcut	76.2 (30)	871 (1600)	1232 (2250)	TiAl
6906	Metcut	76.2 (30)	871 (1600)	1232 (2250)	TiAl
6907	Metcut	76.2 (30)	871 (1600)	1232 (2250)	TiAl
6908	UES	76.2 (30)	899 (1650)	1204 (2200)	Ni-34.3Al
6909	UES	76.2 (30)	899 (1650)	1204 (2200)	Ni-18.1Al
6910	UES	76.2 (30)	899 (1650)	1204 (2200)	Ni-25.8Al
6911	WRDC/MLLM	12.07 (4.75)	RT	427 (800)	Al-2024
6912	WRDC/MLLM	12.07 (4.75)	RT	427 (800)	Al-2024
6913	WRDC/MLLM	12.07 (4.75)	RT	427 (800)	Al-2024
6914	WRDC/MLLM	12.07 (4.75)	RT	427 (800)	Al-2024
6915	WRDC/MLLM	12.07 (4.75)	RT	204 (400)	Al-2024
6916	WRDC/MLLM	12.07 (4.75)	RT	204 (400)	Al-2024
6917	WRDC/MLLM	12.07 (4.75)	RT	204 (400)	Al-2024
6918	WRDC/MLLM	12.07 (4.75)	RT	204 (400)	Al-2024
6919	WRDC/MLLM	12.07 (4.75)	RT	316 (600)	Al-2024
6920	WRDC/MLLM	12.07 (4.75)	RT	316 (600)	Al-2024
6921	WRDC/MLLM	12.07 (4.75)	RT	316 (600)	Al-2024

Forging Operations

Forging No.	Source	Ram Speed cm/s (in/s)	Die Temp C (F)	Billet Temp C (F)	Billet Composition
6922	WRDC/MLLM	12.07 (4.75)	RT	316 (600)	Al-2024
6923	WRDC/MLLM	12.07 (4.75)	RT	316 (600)	Al-2024
6924	WRDC/MLLM	12.19 (4.8)	316 (600)	1093 (2000)	IN-718
6925	WRDC/MLLM	12.19 (4.8)	316 (600)	1093 (2000)	IN-718
6926	WRDC/MLLM	12.19 (4.8)	316 (600)	1093 (2000)	IN-718
6927	WL/POOX-3	76.2 (30)	RT	RT	Ag tube filled superconductor powder
6928	WL/POOX-3	76.2 (30)	RT	RT	Ag tube filled superconductor powder
6929	WL/POOX-3	76.2 (30)	RT	RT	Ag tube filled superconductor powder
6930	WL/POOX-3	76.2 (30)	RT	RT	Ag tube filled superconductor powder
6931	WRDC/MLLM	11.94 (4.7)	260 (500)	982 (1800)	Ti
6932	WRDC/MLLM	76.2 (30)	260 (500)	982 (1800)	Ti
6933	WRDC/MLLM	11.94 (4.7)	260 (500)	982 (1800)	Ti
6934	WRDC/MLLM	11.94 (4.7)	260 (500)	982 (1800)	Ti
6935	WRDC/MLLM	76.2 (30)	260 (500)	982 (1800)	TI
6936	WRDC/MLLM	76.2 (30)	260 (500)	982 (1800)	Ti
6937	WRDC/MLLM	76.2 (30)	260 (500)	982 (1800)	Ti
6938	WL/POOX-3	76.2 (30)	871 (1600)	871 (1600)	Stainless ring with Bismuth
6939	WL/POOX-3	76.2 (30)	749 (1380)	749 (1380)	Stainless ring with Bismuth
6940	WL/POOX-3	76.2 (30)	749 (1380)	749 (1380)	Stainless ring with Bismuth
6941	WL/POOX-3	76.2 (30)	749 (1380)	749 (1380)	Stainless ring with Bismuth

Forging Operations

Forging No.	Source	Ram Speed cm/s (in/s)	Die Temp C (F)	Billet Temp C (F)	Billet Composition
6942	WL/POOX-3	76.2 (30)	749 (1380)	749 (1380)	Stainless ring with Bismuth
6943	WL/POOX-3	76.2 (30)	749 (1380)	749 (1380)	Stainless ring with Bismuth
6944	WRDC/MLLM	11.94 (4.7)	260 (500)	1010 (1850)	IN-718
6945	WRDC/MLLM	11.94 (4.7)	316 (600)	1010 (1850)	IN-718
6946	WRDC/MLLM	11.94 (4.7)	316 (600)	1010 (1850)	IN-718
6947	WRDC/MLLM	11.94 (4.7)	316 (600)	1010 (1850)	IN-718
6948	WRDC/MLLM	11.94 (4.7)	316 (600)	1010 (1850)	IN-718
6949	WRDC/MLLM	11.94 (4.7)	316 (600)	1010 (1850)	IN-718
6950	WRDC/MLLM	11.94 (4.7)	316 (600)	1010 (1850)	IN-718
6951	WRDC/MLLM	11.94 (4.7)	316 (600)	1010 (1850)	IN-718
6952	WRDC/MLLM	11.94 (4.7)	316 (600)	1010 (1850)	IN-718
6953	WRDC/MLLM	11.94 (4.7)	316 (600)	1010 (1850)	IN-718
6954	WRDC/MLLM	11.94 (4.7)	316 (600)	1010 (1850)	IN-718
6955	WRDC/MLLM	11.43 (4.5)	316 (600)	1135 (2075)	IN-718
6956	WRDC/MLLM	11.43 (4.5)	316 (600)	1135 (2075)	IN-718
6957	WRDC/MLLM	11.43 (4.5)	316 (600)	1135 (2075)	IN-718
6958	WRDC/MLLM	11.43 (4.5)	316 (600)	1135 (2075)	IN-718
6959	WRDC/MLLM	11.43 (4.5)	316 (600)	1010 (1850)	IN-718
6960	WRDC/MLLM	11.43 (4.5)	316 (600)	1135 (2075)	IN-718
6961	WRDC/MLLM	11.94 (4.7)	316 (600)	1010 (1850)	IN-718
6962	WRDC/MLLM	11.94 (4.7)	316 (600)	1010 (1850)	IN-718
6963	WRDC/MLLM	11.94 (4.7)	316 (600)	1010 (1850)	IN-718
6964	WRDC/MLLM	11.94 (4.7)	316 (600)	1010 (1850)	IN-718
6965	WRDC/MLLM	11.94 (4.7)	316 (600)	1010 (1850)	IN-718
6966	WRDC/MLLM	11.94 (4.7)	538 (1000)	1135 (2075)	IN-718
6967	WRDC/MLLM	11.94 (4.7)	538 (1000)	1135 (2075)	IN-718

Forging Operations

Forging No.	Source	Ram Speed cm/s (in/s)	Die Temp C (F)	Billet Temp C (F)	Billet Composition
6968	WRDC/MLLM	11.94 (4.7)	538 (1000)	1135 (2075)	IN-718
6969	WRDC/MLLM	11.94 (4.7)	538 (1000)	1135 (2075)	IN-718
6970	WRDC/MLLM	11.94 (4.7)	538 (1000)	1135 (2075)	IN-718
6971	WRDC/MLLM	11.94 (4.7)	538 (1000)	1135 (2075)	IN-718
6972	WRDC/MLLM	11.94 (4.7)	538 (1000)	1135 (2075)	IN-718
6973	WRDC/MLLM	11.94 (4.7)	538 (1000)	1135 (2075)	IN-718
6974	WRDC/MLLM	11.94 (4.7)	538 (1000)	1135 (2075)	IN-718
6975	WRDC/MLLM	11.94 (4.7)	538 (1000)	1135 (2075)	IN-718
6976	WRDC/MLLM	11.94 (4.7)	538 (1000)	1135 (2075)	IN-718
6977	WRDC/MLLM	11.94 (4.7)	649 (1200)	1135 (2075)	IN-718
6978	WRDC/MLLM	11.94 (4.7)	649 (1200)	1135 (2075)	IN-718
6979	WRDC/MLLM	11.94 (4.7)	649 (1200)	1135 (2075)	IN-718
6980	WRDC/MLLM	11.94 (4.7)	649 (1200)	1135 (2075)	IN-718
6981	WRDC/MLLM	11.94 (4.7)	649 (1200)	1135 (2075)	IN-718
6982	WRDC/MLLM	11.94 (4.7)	649 (1200)	1135 (2075)	IN-718
6983	WRDC/MLLM	11.94 (4.7)	649 (1200)	1135 (2075)	IN-718
6984	WRDC/MLLM	11.94 (4.7)	649 (1200)	1135 (2075)	IN-718
6985	WRDC/MLLM	11.94 (4.7)	204 (400)	1316 (2400)	Ti
6986	WRDC/MLLM	11.94 (4.7)	204 (400)	1316 (2400)	Ti
6987	WRDC/MLLM	11.94 (4.7)	204 (400)	1316 (2400)	Ti
6988	WRDC/MLLM	11.94 (4.7)	204 (400)	1316 (2400)	Ti
6989	WRDC/MLLM	11.94 (4.7)	204 (400)	1316 (2400)	Ti
6990	WRDC/MLLM	11.94 (4.7)	204 (400)	1316 (2400)	Ti
6991	WRDC/MLLM	11.94 (4.7)	649 (1200)	1135 (2075)	IN-718
6992	WRDC/MLLM	11.94 (4.7)	649 (1200)	1135 (2075)	IN-718
6993	WRDC/MLLM	11.94 (4.7)	649 (1200)	1135 (2075)	IN-718
6994	WRDC/MLLM	11.94 (4.7)	649 (1200)	1135 (2075)	IN-718

Forging Operations

Forging No.	Source	Ram Speed cm/s (in/s)	Die Temp C (F)	Billet Temp C (F)	Billet Composition
6995	WRDC/MLLM	11.94 (4.7)	649 (1200)	1135 (2075)	IN-718
6996	WRDC/MLLM	11.94 (4.7)	649 (1200)	1135 (2075)	IN-718
6997	WRDC/MLLM	11.94 (4.7)	649 (1200)	1135 (2075)	IN-718
6998	WRDC/MLLM	11.94 (4.7)	649 (1200)	1135 (2075)	IN-718
6999	WRDC/MLLM	11.94 (4.7)	649 (1200)	1135 (2075)	IN-718
7000	WRDC/MLLM	11.94 (4.7)	649 (1200)	1135 (2075)	IN-718
7001	WRDC/MLLM	11.94 (4.7)	649 (1200)	1135 (2075)	IN-718
7002	WRDC/MLLM	11.94 (4.7)	649 (1200)	1135 (2075)	IN-718
7003	WRDC/MLLM	11.94 (4.7)	649 (1200)	1329 (2425)	Ti
7004	WRDC/MLLM	11.94 (4.7)	649 (1200)	1329 (2425)	Ti
7005	WRDC/MLLM	11.94 (4.7)	649 (1200)	1329 (2425)	IN-718
7006	WRDC/MLLM	11.94 (4.7)	649 (1200)	1329 (2425)	Ti
7007	WRDC/MLLM	11.94 (4.7)	649 (1200)	1329 (2425)	Ti
7008	WRDC/MLLM	11.94 (4.7)	649 (1200)	1329 (2425)	Ti
7009	WRDC/MLLM	11.94 (4.7)	649 (1200)	1329 (2425)	TI
7010	WRDC/MLLM	11.94 (4.7)	649 (1200)	1329 (2425)	Ti
7011	UES	11.68 (4.6)	RM	371 (700)	Al-6061-T6
7012	UES	11.68 (4.6)	RM	371 (700)	Al-6061-T6
7013	UES	11.68 (4.6)	RM	371 (700)	Al-6061-T6
7014	UES	11.68 (4.6)	RM	371 (700)	Al-6061-T6
7015	UES	11.68 (4.6)	RM	371 (700)	Al-6061-T6
7016	UES	11.68 (4.6)	RM	371 (700)	Al-6061-T6
7017	UES	11.68 (4.6)	RM	371 (700)	Al-6061-T6